State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS

PUBLIC HEARING TO CONSIDER AMENDMENTS ADOPTING MORE STRINGENT EMISSION STANDARDS FOR 2007 AND SUBSEQUENT MODEL YEAR NEW HEAVY-DUTY DIESEL ENGINES

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EXECUTIVE SUMMARY

Heavy-duty diesel engines (HDDE) are used in a variety of applications such as large trucks, school buses, and motor homes. For large trucks in particular, HDDEs have proven to be reliable, durable, and very fuel efficient. Because of this, HDDEs play a vital role in the transportation of goods and material in California, as well as the rest of the nation. Consequently, the use of HDDEs is a key element of a strong economy.

Compared to gasoline-fueled automobiles and light-duty trucks, HDDEs have significantly lagged behind with respect to the use of aftertreatment-based emission control systems. This is primarily because regulatory agencies have acknowledged that HDDEs emit relatively low levels of hydrocarbons, and efforts to reduce oxides of nitrogen (NOx) emissions would likely adversely impact the HDDE's fuel economy advantage. However, in recent years, the "benefits" of HDDEs have been overshadowed by the increase in their relative contribution of NOx emissions to the overall State inventory and by their potential for causing cancer. Specifically, the Air Resources Board (ARB) identified diesel particulate matter (PM) as a toxic air contaminant in 1998.

In October of 2000, the United States Environmental Protection Agency (U.S. EPA) adopted a rule that reaffirmed[1] emission standards for 2004 and subsequent model year HDDEs.[2] This rulemaking also included supplemental test procedures required for certification in addition to the existing Federal Test Procedure (FTP). Because aftertreatment technologies for diesel engines have been fully developed for PM and are on the near horizon for NOx, the U.S. EPA, in January of 2001, followed the 2004 Final Rule with another rule to reduce emission standards for 2007 and subsequent model year heavy-duty engines,[3] including both spark-ignited (e.g., gasoline-fueled) and compression-ignited (e.g., diesel-fueled) engines. These emission standards represent a 90% reduction of NOx emissions, 72% reduction of non-methane hydrocarbon (NMHC) emissions, and 90% reduction of PM emissions compared to the 2004 emission standards. In addition to the more stringent emission standards, the U.S. EPA adopted minor changes to the previously adopted supplemental test procedures.

The 2007 Final Rule breaks new ground by setting emission standards that require aftertreatment-based technologies. The 2007 Final Rule is analogous to the regulations which first required the use of aftertreatment devices (i.e., catalytic converters) on gasoline-fueled automobiles and light-duty trucks in the mid 1970s. The 2007 Final Rule will also be

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[1] The emission standards were originally promulgated in October 1997.
[2] U.S. EPA's 2004 Final Rule on the Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements (65 FR 59896, October 6, 2000). Referred to as the U.S. EPA's 2004 Final Rule or 2004 Final Rule.
[3] U.S. EPA's 2007 Final Rule on the Control of Emissions of Air Pollution from 2007 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements (66 FR 5002, January 18, 2001). Referred to as the U.S. EPA's 2007 Final Rule or 2007 Final Rule.

a “systems” approach in that it will require the use of low sulfur fuel, analogous to the requirement for unleaded gasoline in the mid 1970s.

The ARB staff is proposing that the Board adopt nearly identical emission standards, test procedures, and other requirements contained in the U.S. EPA’s 2007 Final Rule. Although the proposal will include diesel certification test fuel specifications, a major difference in this proposal is the low sulfur, in-use diesel fuel requirement. A proposal to require the production of low sulfur, in-use diesel fuel will be part of a separate rulemaking scheduled to be presented to the Board in 2002. In addition to the emission standards and test procedures, other requirements to be proposed include the elimination of the exemption that allows turbocharger-equipped engines to vent crankcase emissions to the ambient air. The proposed amendments will not apply to heavy-duty spark-ignited engines and vehicles. Similar emission standard and test procedure requirements for the spark-ignited engines and vehicles are scheduled for consideration in 2002.

The proposal ensures that the requirements for 2007 and subsequent model year HDDEs are identical to those adopted by the U.S. EPA in January 2001. By adopting the proposed reduced emission standards, the ARB is expecting to reduce NOx emissions by 49 tons per day, reactive organic gas (ROG) emissions by 2 tons per day, and PM emissions by 3 tons per day in 2010 statewide, from California and out-of-state registered medium-duty and heavy-duty vehicles. Harmonizing the existing ARB medium-duty CO emission standard with the U.S. EPA’s 2007 and subsequent model year HDDE emission standard, however, will result in an increase in statewide CO emissions by 0.1 tons per day in 2010.

If the entire hardware costs, due to the federal requirements, are passed on to the consumer, heavy-duty vehicle retail prices would increase by approximately $2,100 to $3,400 per medium-duty and heavy-duty diesel vehicle. Further, operating costs are expected to increase by approximately $500 to $3,400 per medium-duty and heavy-duty diesel vehicle in present value over its lifetime. The operating cost increases are due to maintenance of the aftertreatment system, maintenance of the closed crankcase system, low sulfur diesel fuel, and additional maintenance savings. Based on the total cost increase, the cost effectiveness of the proposed reduced emission standards ranges from $0.29 to $0.63 per pound of NOx and NMHC emissions reduced and from $3.03 to $6.65 per pound of PM emissions reduced. This compares to the cost-effectiveness of California mobile source and motor vehicle fuels regulations adopted over the past decade that ranges from $0.17 to $2.55 per pound of ozone precursors (NOx and NMHC) reduced and approximately $17.90 per pound of PM reduced.

I. INTRODUCTION

California is the only state that has the authority to establish new mobile source emission standards and/or test procedures that differ from federal standards and test procedures (Federal Clean Air Act Section 209(b)). California emission standards and test procedures must be, in the aggregate, at least as protective of public health and welfare as applicable federal standards and test procedures. This proposal is an effort to align California emission requirements with federal requirements to further reduce emissions from a significant emissions source.

Heavy-duty diesel motor vehicles, with a gross vehicle weight rating (GVWR) of 14,001 pounds and greater, contribute a large portion of California's inventory of several key air pollutants including NOx, ROG, and PM. Both NOx and ROG are precursors to ozone. Ozone is a concern because it has been shown to adversely impact human health. NOx alone can also be harmful to humans by aggravating common respiratory illnesses and even prematurely aging lung tissue. NOx can also be transformed in the atmosphere to nitrate, a form of PM that can cause lung disease and premature death. Further, in August of 1998, California identified diesel PM as a toxic air contaminant. Assessment of carcinogenic risk in California due to diesel PM accounts for approximately 70 percent of all air toxics in 2000. Statewide, the average potential cancer risk associated with diesel PM is over 500 excess cases per million people.[4] Further information on adverse health effects of diesel PM can be found in the ARB's Diesel Risk Reduction Plan.[5]

On-road heavy-duty diesel vehicles are estimated to account for as much as 28 percent of the statewide mobile source NOx inventory and 16 percent of the statewide mobile source exhaust PM inventory in 2010. This is of particular concern due to the relatively small population of heavy-duty diesel vehicles. Compared to emissions from passenger cars, to date heavy-duty diesel vehicle emissions have been less controlled. While catalytic converters have been required on passenger cars for over 30 years, diesel exhaust from HDDEs is released directly into the atmosphere. Currently, there are many demonstration projects ongoing worldwide to show the effectiveness of heavy-duty diesel aftertreatment devices. Additionally, improvements to the effectiveness of these devices are ongoing.

This proposal will apply to HDDEs and medium-duty diesel engines (MDDE). The ARB is proposing to align both the heavy-duty and medium-duty emission standards with those adopted in the U.S. EPA's 2007 Final Rule. This will result in a decrease to the medium-duty NOx, NMHC, and PM emission standards and a slight increase in the medium-duty

[4] The Scientific Review Panel concluded that 300 excess cancers per million people, per microgram per cubic meter of diesel PM, is appropriate as a point estimate of unit risk.

[5] Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles, Air Resources Board - Stationary Source Division and Mobile Source Control Division, October 2000. This and many other ARB documents mentioned in this report are available on the internet at http://www.arb.ca.gov/.

CO emission standard. Unlike the U.S. EPA's 2007 Final Rule, this proposal will not apply to spark-ignited engines and vehicles, except those that are "derived from the diesel-cycle engine."[6] For those that are not derived from a diesel-cycle engine, separate spark-ignited engine and vehicle emission standards will be included in a proposal scheduled for consideration by the Board in 2002. Since the proposed emission standards will dramatically reduce emission levels, there has been concern about how to measure these emissions during certification. Therefore, identical to the U.S. EPA's 2007 Final Rule, the proposal also includes new and amended calibration and sampling methods.

Due to the extensive demonstration of aftertreatment devices, the U.S. EPA and the ARB consider these devices the next step to control emissions from diesel engines. Demonstration programs have shown the effectiveness of NOx reduction technologies such as NOx adsorbers and selective catalytic reduction (SCR). Separate demonstration programs have shown the effectiveness of PM reduction technologies such as oxidation catalysts, diesel particulate filters, and catalyzed particulate filters. Most recent data show that NOx adsorbers in conjunction with diesel particulate filters, or catalyzed particulate filters, can provide the necessary reductions in emissions to meet the proposed emission standards.

Many of the catalyst-based aftertreatment systems are sensitive to the sulfur content in the diesel fuel. Therefore, the proposal includes a lower emission test and service accumulation diesel fuel, sulfur content specification. However, in-use diesel fuel sulfur requirements are not included in this proposal. They will be included in a separate proposal scheduled for consideration by the Board in 2002 that will consider the benefits of maintaining a separate in-use California diesel fuel. The U.S. EPA has already adopted national low sulfur diesel fuel requirements, in their 2007 Final Rule, that will provide a backstop and ensure availability of the low sulfur, in-use diesel fuel.

In addition to the review of the U.S. EPA's Regulatory Impact Analysis for their 2007 Final Rule, ARB staff also reviewed on-going research and demonstration projects conducted by various government and industry groups. Review of current data has shown that the proposed requirements are technically feasible in the proposed time frame.

The remainder of this report provides details of the proposal. It discusses the feasibility of the proposed emission standards and cost effectiveness of the proposal. In addition, emission reduction calculations are provided. The proposal is consistent with the requirements adopted by the U.S. EPA so that similar engines can be produced in California as well as the rest of the nation.

The following is a summary of each Section of this Staff Report.

[6] Pursuant to Title 13, California Code of Regulations, Section 1956.8.

- Sections I and II of the Staff Report contain the introduction and background, respectively.
- Section III contains a discussion on the need for the proposed emission standards.
- Section IV is a summary of the proposed requirements.
- Section V describes areas in which the proposal differs from the federal requirements.
- Section VI addresses the technological feasibility of the proposal.
- Section VII discusses remaining issues that have arisen during the development of the requirements, and discusses how the issues are addressed by the proposal.
- Section VIII describes the regulatory alternatives that were considered.
- Section IX discusses the economic impacts.
- Section X assesses the environmental impacts of the proposal, along with the cost-effectiveness analysis for the proposal.
- Section XI summarizes the staff's findings and recommendations.
- Section XII lists references used in this Staff Report.

II. BACKGROUND

This section provides an overview of the emissions from diesel engines, the current regulations and the State Implementation Plan (SIP) commitments for HDDEs.

A. HEAVY-DUTY DIESEL-CYCLE ENGINES

Diesel-cycle engines are those engines that use a compression-ignited system to initiate combustion of the fuel in the engine's combustion chamber. By contrast, a spark-ignited engine typically uses a spark plug to ignite the fuel. However, regardless of how the fuel is ignited, if engines are derived from diesel-cycle engines[7] (i.e., having similar torque-speed characteristics and are used in similar vehicle applications as HDDEs), they would be subject to the proposed HDDE regulatory requirements. Thus, spark-ignited natural gas fueled engines and liquefied petroleum gas fueled engines that are derived from the diesel-cycle engine would, for the purposes of this rulemaking, be considered HDDEs.

The proposed emission standards would apply to HDDEs and would be optional for MDDEs.[8] HDDEs are used in vehicles with a GVWR of 14,001 pounds and greater. MDDEs are used in vehicles with a GVWR of 8,501 to 14,000 pounds. MDDEs have the option to certify using chassis-based emission standards or engine-based emission standards. Except for formaldehyde and CO, the current medium-duty diesel engine-based emission standards are identical to the HDDE emission standards.

For emission inventory purposes, HDDEs are segregated into heavy heavy-duty diesel engines and medium heavy-duty diesel engines. Heavy heavy-duty diesel engines are those used in vehicles with a GVWR of 33,001 pounds and greater and medium heavy-duty diesel engines are those used in vehicles with a GVWR of 14,001 to 33,000 pounds. Noteworthy is the inclusion of both school buses and motor homes in the medium heavy-duty vehicle inventory. Weight classifications for the regulatory requirements and emission inventory are summarized in Table 1 below.

[7] Pursuant to Title 13, California Code of Regulations, Section 1956.8.
[8] HDDE emission standards are optional for engines used in medium-duty vehicles 8,501 to 14,000 pounds GVWR, pursuant to the LEV II requirements in Title 13, California Code of Regulations, Section 1956.8(h).

Table 1 - ARB Weight Class Identification and Regulatory Requirements Summary

Regulatory Classification	GVWR (lbs.)	HDDE Standards Required?
Heavy-Duty	14,001 +	Yes
Medium-Duty[9]	8,501 - 14,000	Optional

B. DIESEL ENGINE EMISSIONS

Unlike Otto-cycle (spark-ignited) engines, a typical diesel-cycle engine operates by compression ignition.[10] Diesel fuel is typically injected directly to the combustion chamber and mixed with hot compressed air that is already present. The fuel is ignited by high temperature in the combustion chamber that results from compressing the air, rather than by spark plugs like those used in gasoline-fueled engines. The amount of air introduced into the combustion chamber remains constantly in excess of the chemically ideal stoichiometric air-to-fuel ratio. Power from a diesel engine, is controlled by regulating the amount of fuel that is injected into the combustion chamber.

The primary pollutants of concern from diesel engines are NOx and PM, since both are harmful to human health. The high combustion and exhaust temperatures, and excess air cause the nitrogen in the air to combine with available oxygen to form NOx. Since diesel-cycle combustion operates with excess air, by-products due to incomplete combustion are emitted at relatively low levels. These by-products include HC and CO. Evaporative emissions from diesel engines are not significant since diesel fuel has a low vapor pressure and thus, a low evaporation rate. In addition to the PM emissions resulting from incomplete combustion of fuel, lubrication oil entering the cylinder contributes to overall PM emissions.

Another source of emissions from a diesel engine is the crankcase. Crankcase emissions are similar to exhaust emissions. These emissions result when the combustion gases "blow by" the piston rings into the crankcase. Consequently, these gases are vented to reduce the pressure in the crankcase. Currently, venting crankcase emissions to the ambient air is permitted in all on-road HDDEs equipped with turbochargers, which is essentially all of them. The staff's proposal would require all HDDEs to recirculate the crankcase gases back into the

[9] Includes school buses and motor homes.
[10] Natural gas fueled engines and liquefied petroleum gas fueled engines derived from diesel-cycle engines typically operate using spark-ignition identical to the Otto-cycle engine.

combustion chamber, like is done in gasoline engines.

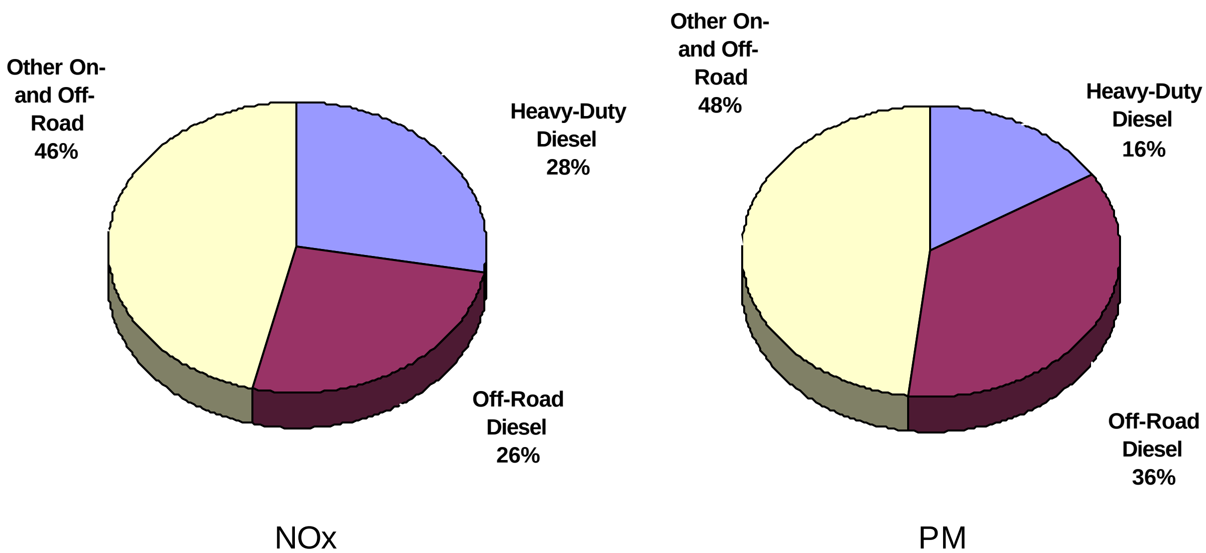
C. EMISSIONS INVENTORY

The modelling program used to determine California's emissions inventory for HDDEs is called EMFAC2000. This program was adopted by the Board in May 2000. The emissions information in this report is based on the updated emissions inventory from EMFAC2000 Version 2.02.[11]

As shown in the charts in Figure 1, the projected NOx and PM emissions from on-road HDDEs will contribute approximately 28 percent of the mobile source NOx emissions and 16 percent of the mobile source exhaust PM emissions in California in 2010. The "other on- and off-road" sources, shown in Figure 1, include passenger cars, gasoline-fueled trucks, motorcycles, and urban buses.

Figure 1

Statewide Mobile Source Emissions in 2010



D. EXISTING EMISSION STANDARDS

In 1995, the U.S. EPA, ARB, and the leading manufacturers of HDDEs signed a Statement of Principles (SOP) with the understanding that the two agencies would harmonize any new emission standards. The SOP is intended to create uniform and consistent standards for heavy-duty engines, due to the widespread affect of heavy-duty trucks that often travel between states. In October 1997, the U.S. EPA

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[11] It should be noted that an update to EMFAC2000, called EMFAC2001, was adopted by the Board in July 2001. To ensure consistent emission calculations throughout this staff report, only results from EMFAC2000 are used.

adopted new emission standards for model year 2004 and subsequent model year HDDEs. In February 1998, the ARB subsequently adopted identical, new HDDE standards for the same model years to harmonize the heavy-duty vehicle regulations between the ARB and the U.S. EPA. For 2004 and subsequent model year HDDEs, manufacturers will have the flexibility to certify their engines to one of the two options given in Table 2, below.

Table 2 - ARB and U.S. EPA Emission Standards for MY 2004 and Subsequent Heavy-Duty Diesel-Cycle Engines (grams per brake horsepower-hour) [12]

Option	NMHC plus NOx	NMHC[13]	CO	PM
1	2.4	n/a	15.5	0.10
2	2.5	0.5	15.5	0.10

MDDEs have the option to certify using either a chassis test or an engine test. For the chassis test, the applicable emission standards are shown below in Tables 3 and 4.

Table 3 - ARB Emission Standards for MY 2004 and Subsequent Medium-Duty Diesel Vehicles, GVWR 8,501-10,000 lbs. (grams per mile)

Option	NMOG	NOx	CO	PM	Formaldehyde[14]
LEV	0.195	0.2	6.4	0.12	32
ULEV	0.143	0.2	6.4	0.06	16
SULEV	0.100	0.1	3.2	0.06	8

Table 4 - ARB Emission Standards for MY 2004 and Subsequent Medium-Duty Diesel Vehicles, GVWR 10,001-14,000 lbs. (grams per mile)

Option	NMOG	NOx	CO	PM	Formaldehyde[15]
LEV	0.230	0.4	7.3	0.12	40

[12] The emission standards shown apply to all heavy-duty diesel engines except urban bus engines.
[13] The NMHC emission standard shown in this table is the NMHC portion of the NOx plus NMHC emission standard. This emission standard is maximum allowable portion of the NOx plus NMHC emission standard.
[14] Medium-duty diesel vehicle formaldehyde emission standards are displayed in terms of milligrams per mile.
[15] Medium-duty diesel vehicle formaldehyde emission standards are displayed in terms of milligrams per mile.

ULEV	0.167	0.4	7.3	0.06	21
SULEV	0.117	0.2	3.7	0.06	10

For the engine test, MDDEs may certify to the same emission standards as those of HDDEs. The 2004 and subsequent model year MDDEs are required to certify to the ULEV emission standards or equivalent fleet average non-methane organic gas (NMOG) requirements. These engines also have the flexibility to certify their engines to one of the two ultra-low-emission-vehicle (ULEV) options using an engine test. In addition, MDDEs, may certify their engines to a super-ultra-low-emission-vehicle (SULEV) emission standard that is equivalent to one half of the ULEV emission standard (except for the NOx plus NMHC emission standard that is 83% of the ULEV emission standard). Engines certified to the SULEV emission standard may generate NMOG vehicle-equivalent credits (VEC). The VECs can, in turn, be used to assist a manufacturer in meeting medium-duty diesel vehicle phase-in requirements. The optional, engine test-based emission standards are given in Table 5, below.

Table 5 - ARB Emission Standards for MY 2004 and Subsequent Medium-Duty Diesel Engines (grams per brake horsepower-hour)

Option	NMHC plus NOx	NMHC[16]	CO	PM	Formaldehyde
ULEV A	2.4	n/a	14.4	0.10	0.05
ULEV B	2.5	0.5	14.4	0.10	0.05
SULEV	2.0	n/a	7.2	0.05	0.025

It should be noted that, unlike HDDEs, MDDEs are required to comply with a formaldehyde emission standard (see Table 5, above). The primary reason for this is that compared to HDDEs, many MDDEs are fueled by natural gas or liquefied petroleum gas. These alternative fuels tend to produce higher levels of formaldehyde compared to a diesel-fueled engine.

E. EXISTING TEST PROCEDURES

Currently, California's 2005 and subsequent model year HDDEs[17] require compliance with several emission tests for certification of engines including the federal test procedure (FTP), the Not-to-Exceed (NTE) test, and the Euro III European Stationary Cycle (ESC) test. The FTP test cycles the engine through a fixed set of conditions meant to simulate actual driving, both urban stop and go

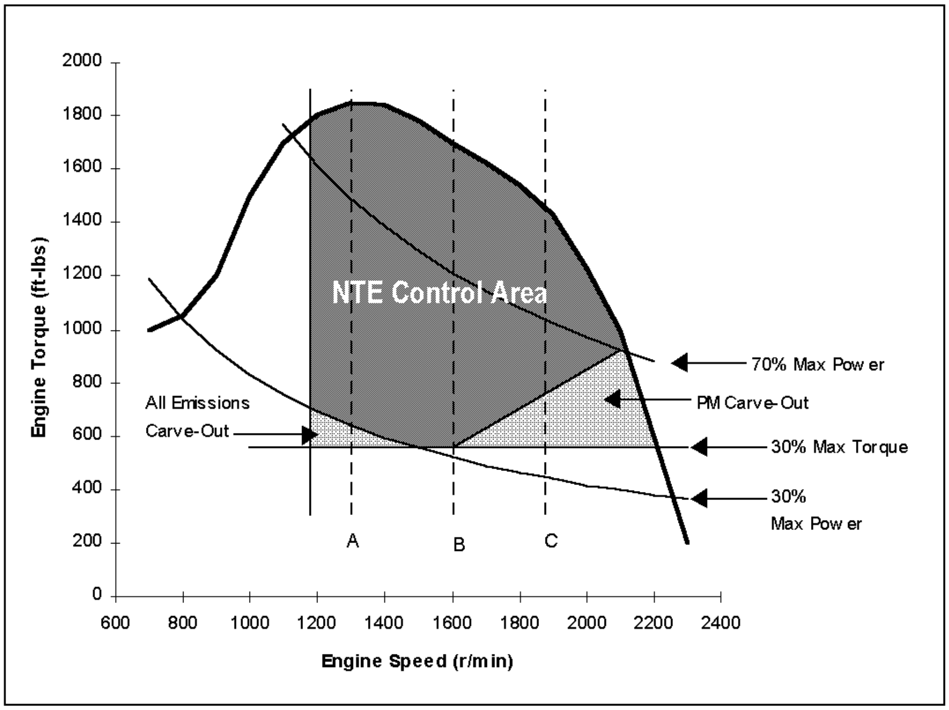
[16] The NMHC emission standard shown in this table is the NMHC portion of the NOx plus NMHC emission standard. This emission standard is maximum allowable portion of the NOx plus NMHC emission standard.
[17] Regulatory documents can be found at http://www.arb.ca.gov/regact/ntetest/ntetest.htm.

traffic, and crowded freeway/expressway traffic. However, the FTP alone is not adequate to ensure that emissions are controlled during all in-use driving conditions. As a result, in December 2000, the ARB adopted additional test procedures, the NTE test and the ESC test. The adopted test procedures are similar to those required in the heavy-duty diesel consent decrees and the U.S. EPA's 2004 Final Rule and became effective in California on July 25, 2001.

The NTE test, as defined in 40 CFR §86.1370-2007, establishes an area (NTE control area) under the torque curve of an engine where emissions must not exceed a specified emission cap for a given pollutant. Instead of using a fixed operating cycle, the NTE covers an area of operation, or the NTE control area. Emissions sampled while operating the engine within the control area, are limited to the NTE emissions cap. The basic NTE control area for diesel engines has three basic boundaries on the engine's torque and speed map. The first is the upper boundary that is represented by an engine's maximum torque at a given speed. The second boundary is 30 percent of maximum torque. Only operation above this second boundary is included in the NTE control area. The third boundary is determined based on the lowest engine speed at 50 percent of maximum power and highest engine speed at 70 percent of maximum power. This engine speed is considered the "15 percent operational engine speed". Only engine operation above that engine speed is included in the NTE control area. The control area is bound by operating conditions typical of in-use operation with the exception of two "carve-out" areas of operation. The first carve out area applies to emissions of all air contaminants. All engine operation less than 30 percent of maximum power is removed from the basic NTE control area on the engine's torque and speed map, since excess emissions are unlikely to occur in this operating region. The second carve-out area is determined from several engine power, torque, and speed points. This carve-out area excludes only PM emissions from the NTE control area. The NTE cap is based on the FTP emission standard and includes a 25 percent allowance to comply with the NTE test. The minimum sampling time for this test is 30 seconds, where average NTE emissions over a 30-second interval must comply with the emissions cap. A sample NTE control area is shown in Figure 2, below.

Figure 2

Example NTE Control Area for Heavy-Duty Diesel Engine With 100% Operational Engine Speed Less Than 2400 rpm

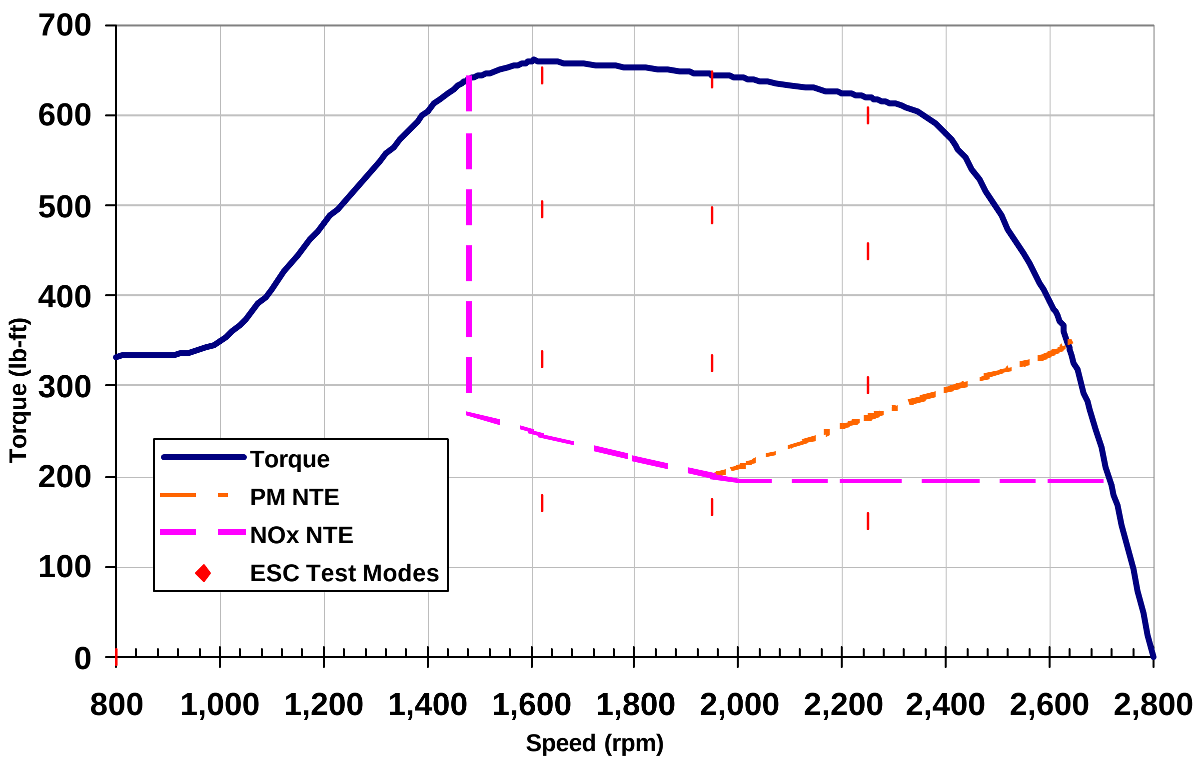


The NTE test also includes two temperature and altitude options to comply with the test requirements. Combinations of temperature and altitude create a NTE zone that is typical of California driving conditions. NOx and PM emission results at temperatures outside the NTE zone are corrected to the levels at the boundaries of the NTE zone. Due to the flexibility of the NTE control area, the NTE test may be conducted in an emission testing laboratory or on the road.

As opposed to transient testing conducted with the NTE test, the ESC test consists of steady state operation. The Euro III ESC test cycle, defined in 40 CFR §86.1360-2007 as the "supplemental steady state test", consists of 13 modes at specified speed and power conditions, primarily representing the typical highway cruise operating conditions of heavy-duty diesel vehicles. The sum of the weighted emission results at each test mode is compared to the FTP-based emission standard. Maximum allowable emission limits (MAEL) are determined through interpolation of the 12 non-idle test points (the thirteenth operating mode, idle, is excluded) of the ESC test. A 10 percent interpolation allowance is added to the results of each of the 12 test points. The 10 percent allowance is added to provide additional allowance for possible errors in interpolation. Three random test points may be selected, by the ARB, within the MAEL area to verify that emissions do not exceed the MAEL cap. A sample of the ESC test modes is shown in Figure 3. The test modes are shown compared to a NTE control zone.

Figure 3

Example ESC Test Modes with NTE Control Area for Heavy-Duty Diesel Engine



F. CERTIFICATION TEST FUEL SPECIFICATIONS

The current diesel sulfur content specification for certification test fuel ranges from 100 to 500 parts per million. This specification is identical for both exhaust emission testing and service accumulation. Manufacturers also have the option to use an alternative certification test fuel provided there is sufficient evidence indicating that this test fuel will be the predominant in-use fuel.

G. EXISTING AVERAGING, BANKING, AND TRADING PROGRAM

Currently, 2007 and subsequent model year heavy-duty engine manufacturers may include any or all engine families in the averaging, banking, and trading (ABT) program. In the ABT program, an engine manufacturer may “average” among current model year engine families, “bank” emissions from current model year engine families, and “trade” banked emissions to other engine manufacturers. Averaging and trading of banked emissions may only be completed between engine families within the same “averaging set.” Averaging sets are based on the U.S. EPA’s weight classes, shown in Table 6 below.

Table 6 - U.S. EPA Weight Class/Averaging Set Identification

U.S. EPA and ARB	GVWR (lbs.)
Heavy Heavy-Duty	33,001+
Medium Heavy-Duty	19,501 - 33,000
Light Heavy-Duty	8,501 - 19,500

For ABT purposes only, the light heavy-duty engine averaging set includes ARB medium-duty engines (GVWR between 8,501 and 14,000 pounds) and a small portion of ARB heavy-duty engines (GVWR between 14,001 and 19,500 pounds). Additionally, there may be multiple engine families in each averaging set.

NMHC and PM credits generated in the ABT program have no expiration date. However, NOx credits generated in the ABT program are only available for 3 model years following the model year of credit generation. Further, credits generated before 2004 from engines sold outside California, may not be used to certify light heavy-duty and medium-duty engines sold in California. While the ABT program provides flexibility by allowing averaging, it does specify upper limits to the engine family emission limits (FEL). The current FEL upper limits are shown in the table below.

Table 7 – Current Family Emission Limits (grams per brake horsepower-hour)

NOx + NMHC	NMHC[18]	PM
4.5	0.50	0.25

H. STATE IMPLEMENTATION PLAN (SIP)

In November 1994, the ARB approved the SIP for Ozone, which outlines the measures to be taken to bring the state’s air quality into attainment with the federal ambient air quality standards for ozone. During the SIP’s development, it became

[18] NMHC FEL is for engine families certifying to the optional emission standards.

clear that reducing emissions of NOx from on-road HDDEs operating within the state is imperative for cleaning California's air.

Although many of the measures included in the SIP have been adopted, State air quality goals are still not expected to be satisfied in the necessary timeframes. This proposal is expected to further reduce emissions of NOx, PM, and ROG to help meet California's air quality goals.

I. DIESEL RISK REDUCTION PLAN

In August of 1998, California identified diesel PM as a toxic air contaminant. Diesel PM has been found to contain over 40 substances that are individually identified as toxic air contaminants and is associated with increases in lung disease, heart disease, mortality, and other chronic non-cancer health effects. In addition, an assessment of carcinogenic risk in California finds diesel PM to account for approximately 70 percent of the total ambient cancer risk in 2000. Statewide, the average potential cancer risk associated with diesel PM is over 500 excess cases per million people.[19] In September 2000, the ARB approved the Diesel Risk Reduction Plan which identified the impacts of diesel PM, identified current technologies to control diesel PM, and outlined measures necessary to reduce diesel PM. One measure included in the Diesel Risk Reduction Plan is the adoption of lower PM emission standards for new HDDEs. These emission standards are contained in the staff proposal and are identical to the emission standards adopted by the U.S. EPA in their 2007 Final Rule.

[19] The Scientific Review Panel concluded that 300 excess cancers per million people, per microgram per cubic meter of diesel PM, is appropriate as a point estimate of unit risk.

III. NEED FOR CONTROL

The proposed emission standards will provide additional emission reductions beyond those estimated to result from the measures identified in the 1994 SIP for Ozone. This section summarizes the air quality need that justifies the proposed emission standards.

Simply put, without further emission controls, California will not attain state air quality standards. As shown previously in Figure 1, on-road HDDEs are a significant contributor to statewide NOx and PM emissions. The projected statewide NOx and PM emissions from these engines in 2010 will contribute approximately 28 percent of the mobile source NOx emissions and 16 percent of the mobile source exhaust PM emissions. In 2020, the projected statewide NOx contribution becomes 34 percent of the mobile source NOx inventory (the PM contribution remains at 16 percent). From these projections, it is clear that if California is expected to attain state air quality standards, additional controls are necessary for HDDEs. Thus, given the favorable cost effectiveness and lack of aftertreatment control strategies on current HDDEs, emissions from HDDEs are a good target for further reductions.

Ozone is a result of the photochemical reaction of primarily NOx and HC. Evidence shows that ozone is the cause of harmful respiratory effects, including chest pain, coughing, and shortness of breath. Those who may be severely affected include children, the elderly, and people with poor respiratory systems. Even healthy people may be affected by the elevated ozone levels if they are active outdoors during smoggy days. NOx can also be transformed in the atmosphere to nitrate, a form of PM that can cause lung disease and premature death. NOx alone can also directly harm human health by aggravating common respiratory illnesses, such as asthma and bronchitis, and contributes to the premature aging of lung tissue and various other chronic lung diseases. In addition to human health effects, negative environmental effects are also associated with ozone and NOx. Ozone has been shown to adversely impact plants and many man-made materials, while NOx contributes to acid deposition and the overgrowth of algae in coastal estuaries.

In addition to harmful NOx, diesel engines also produce diesel exhaust PM. After many years of review, California identified diesel exhaust PM as a toxic air contaminant in August of 1998. A toxic air contaminant is any air pollutant that may cause or contribute to an increase in mortality or serious illness, or that may pose a present or potential hazard to human health. As previously stated, diesel PM contains over 40 substances that are, in themselves, identified as toxic air contaminants. These substances include benzene and formaldehyde to name just two. As a result, assessment of carcinogenic risk in California finds diesel PM to account for approximately 70 percent of the total ambient cancer risk in 2000. Statewide, the average potential cancer risk associated with diesel PM is over 500 excess cases per million people.

IV. SUMMARY OF PROPOSED REQUIREMENTS

The staff recommends that the Board amend section 1956.8, Title 13, California Code of Regulations, and the incorporated “California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles”, as set forth in Appendices 1 and 2. The proposed regulatory language for the emission standards and test procedures duplicate the requirements adopted by the U.S. EPA.[20] Staff proposes to adopt the emission standards and test procedures beginning in the 2007 model year, the same year that these standards and test procedures apply federally. Specific provisions of this proposal include:

HDDE emission standards and phase-in

- More stringent emission standards as follows: NOx emissions at 0.2 grams per brake horsepower-hour, NMHC emissions at 0.14 grams per brake horsepower-hour, and PM emissions at 0.01 grams per brake horsepower-hour,
- NOx and NMHC emission standard phase-in of 50 percent from 2007 through 2009 model years, and 100 percent in 2010 and subsequent model years,
- Full implementation of the HDDE PM emission standard beginning in the 2007 model year,

MDDE emission standards and phase-in

- A slight increase in the MDDE CO emission standard to 15.5 grams per brake horsepower-hour,
- Reduced MDDE SULEV emission standards to half of the proposed PM and CO emission standards,
- Reduced MDDE SULEV emission standards to 83% of the proposed NOx and NMHC emission standards,
- NOx and NMHC emission standard phase-in of 50 percent from 2007 through 2009 model years, and 100 percent in 2010 and subsequent model years,
- Full implementation of the MDDE PM and CO emission standard beginning in the 2007 model year,

Elimination of crankcase emission exemption

[20] Federal regulations published at 66 FR 5002, January 18, 2001.

- Elimination of the crankcase emission exemption from turbocharged HDDEs,

Supplemental emission test procedures

- Elimination of PM "carve-out" areas of the NTE control zone,
- Elimination of the MAEL test and the three "mystery points" for engines that certify to reduced emission standards,
- The allowance of engine deficiencies for 2010 through 2013 model years,

Supplemental emission test procedure caps

- The allowance of higher NOx and PM NTE caps for engines that certify to reduced emission standards,

Certification test fuel specifications

- Reduced sulfur content for emission test and service accumulation fuel,

ABT program

- A revised ABT program that allows trading of emissions between phased-in engines and phased-out engines, and
- A revised ABT program that allows averaging of emissions between weight classes during the phase-in period.

A. APPLICABILITY

The provisions in this proposal apply to all MDDEs and HDDEs[21] produced for sale in California in the 2007 and subsequent model years. MDDEs are used in vehicles with a GVWR of 8,501 to 14,000 pounds. HDDEs are used in vehicles with a GVWR of 14,001 pounds and greater. Although urban bus engines can be classified as HDDEs, this proposal does not apply to urban bus engines. Lower emission standards for urban bus engines have already been adopted by the ARB. Additionally, there are no proposed exemptions for any engines within the heavy-duty or medium-duty weight classes.

B. HEAVY-DUTY DIESEL CYCLE AND MEDIUM-DUTY DIESEL EMISSION STANDARDS

[21] Including both natural gas fueled engines and liquefied petroleum gas fueled engines that are derived from the diesel-cycle engine, as described in Section II.A above.

In contrast to the currently combined NOx plus NMHC emission standard, the proposal includes separate emission standards for NOx and NMHC. The proposal also includes a PM emission standard. There is no proposed change to the existing CO emission standard for HDDEs. However, the ARB is proposing to harmonize the MDDE CO emission standard for ULEVs with the federal emission standard at 15.5 grams per brake horsepower-hour.

MDDEs also have the flexibility to certify their engines to optional SULEV emission standards that would be equivalent to one half of the PM and CO ULEV emission standards (the NOx and NMHC emission standards would be 83% of the ULEV emission standards). The SULEV emission standards are currently used when calculating non-methane organic gas vehicle-equivalent credits and debits. In order to continue allowing the option to certify 2007 and subsequent model year MDDEs to SULEV emission standards for the purpose of generating credits, staff proposes reduced SULEV emission standards, as shown in Table 8, below.

Thus, as shown in Table 8, the proposed HDDE and MDDE ULEV emission standards for NOx, NMHC, PM, and CO are 0.2 grams per brake horsepower-hour, 0.14 grams per brake horsepower-hour, 0.01 grams per brake horsepower-hour, and 15.5 grams per brake horsepower-hour, respectively. The proposed MDDE SULEV emission standards for NOx, NMHC, PM, and CO are 0.17 grams per brake horsepower-hour, 0.12 grams per brake horsepower-hour, 0.005 grams per brake horsepower-hour, and 7.7 grams per brake horsepower-hour, respectively.

Table 8 - Summary of Proposed Heavy-Duty Diesel Cycle and Medium-Duty Diesel Engine Emission Standards (grams per brake horsepower-hour)

ARB Weight Class		**Pollutant**			
		NOx	NMHC	PM	CO
Heavy-Duty		0.2	0.14	0.01	15.5
Medium-Duty	ULEV	0.2	0.14	0.01	15.5[22]
	SULEV	0.17	0.12	0.005	7.7

C. HEAVY-DUTY DIESEL CYCLE AND MEDIUM-DUTY DIESEL EMISSION STANDARDS PHASE-IN

[22] The current ARB heavy-duty diesel-cycle engine CO emission standard is 15.5 grams per brake horsepower-hour. However, the current ARB medium-duty diesel engine CO emission standard is 14.4 grams per brake horsepower-hour. For the purpose of harmonizing with the U.S. EPA, the allowable CO emission standard would be increased to 15.5 grams per brake horsepower-hour.

The above described emission standards for HDDEs and MDDEs are also proposed to be phased-in. The NOx and NMHC emission standards are proposed to be phased-in at 50 percent of engines sold in the 2007 model year, 50 percent in the 2008 model year, 50 percent in the 2009 model year, and 100 percent in the 2010 model year. The proposed implementation of the PM and CO emission standards is 100 percent of engines sold in the 2007 and subsequent model years. Phase-in will be determined based on U.S.-directed production. The phase-in schedule is summarized in Table 9 below.

Table 9 - Summary of Phase-In Schedule

Pollutant	Model Year			
	2007	**2008**	**2009**	**2010+**
NOx NMHC	50%	50%	50%	100%
PM	100%	100%	100%	100%
CO	100%	100%	100%	100%

D. SUPPLEMENTAL TEST PROCEDURE AMENDMENTS

The supplemental test procedures were originally adopted by the Board on December 8, 2000. The proposal includes changes to the test procedures that are identical to those adopted by the U.S. EPA in their 2007 Final Rule and are detailed below.

1. Not-to-Exceed Test Procedure

There are no proposed changes to the basic NTE control area. As previously described under “Existing Test Procedures” (Section II.E), there are currently two areas which are “carved out” of the basic NTE control area. There are no proposed changes to the first carve out area that applies to all air contaminants. The second carve out area that applies to PM emissions is proposed to be removed due to the high efficiency of the PM control technologies that will be necessary to comply with the proposed emission standard. Therefore, removing this “carve out” area will require control of PM emissions over the entire NTE control area.

The NTE requirement will continue to apply under any engine operating condition that could reasonably be expected in normal vehicle use. Since engine manufacturers may potentially utilize aftertreatment devices, the averaging period to determine compliance with the test procedures has been increased. When a regeneration event occurs during the NTE test of an engine equipped with control devices that perform discrete regeneration events, the averaging period is increased to the time between regeneration events multiplied by the number of full regeneration events that occurred. However, this only applies to those engines that send electronic signals that indicate the beginning of a regeneration event.

An additional warm-up allowance is proposed for engines with NOx or NMHC aftertreatment devices. If an engine is equipped with one or more devices that reduce NOx or NMHC emissions, NTE emission caps for NOx and NMHC do not apply when the exhaust temperature (at the outlet of the aftertreatment device) is less than 250 degrees C.

In addition, up to three deficiencies may be approved per engine family for model years 2010 through 2013.[23] Deficiencies during this time period are approved on an engine model and/or horsepower rating basis within an engine family. Additionally, deficiencies are applicable for one model year at a time.

2. Euro III European Stationary Cycle Test Procedure

Since the proposed lower emission standards will not allow as many adjustments outside the ESC test points, MAEL requirements are proposed to be removed for engines with a NOx FEL less than 1.50 grams per brake horsepower-hour.

E. SUPPLEMENTAL TEST EMISSION CAPS

Emission caps for the supplemental test procedures are based on the existing emission limits determined by the FTP test cycle. There are three sets of proposed changes to California's emission caps contained in the test procedures, which are identical to those contained in the U.S. EPA's 2007 Final Rule. Use of the additional caps is based upon the emissions of the certified engine family. The emission cap for the Euro III ESC test will continue to be 1.0 times the FTP emission limit. For engines with a NOx FEL less than 1.50 grams per brake horsepower-hour, the MAEL test will not be required (as mentioned above in Section II.D).

For engines with a NOx FEL less than 1.50 grams per brake horsepower-hour, the NTE cap is proposed to be 1.5 times the applicable NOx or NMHC emission standard or FEL. All other engines with a NOx FEL of 1.50 grams per brake horsepower-hour and greater will continue to be 1.25 times the applicable NOx or NMHC emission standard or FEL. Due to the complete phase-in of the PM emission standards, the PM NTE cap for all 2007 and subsequent model year engines is proposed to be 1.5 times the applicable PM emission standard or FEL. The larger NTE caps are proposed due to the proposed lower emission standards,

[23] Criteria for deficiencies occurring during 2007 through 2009 model years, including phased-in engines, is detailed in the U.S. EPA's 2004 Final Rule.

thereby providing a greater allowance for compliance with the requirements. The proposed changes to the emission caps are summarized in Table 10 below.

Table 10 - Summary of Proposed Emission Caps

Test Procedure	Pollutant	Qualification	Proposed Cap
MAEL	All	NOx < 1.50 g/bhp-hr	Not Required
NTE	NOx	NOx < 1.50 g/bhp-hr	1.5 x FTP standard
	NMHC	NOx < 1.50 g/bhp-hr	1.5 x FTP standard
	PM	None	1.5 x FTP standard

F. CERTIFICATION TEST FUEL SPECIFICATIONS

To ensure that the proper fuel is used for emissions testing and service accumulation, the certification test fuel sulfur content specification is proposed to range from 7 to 15 parts per million. Manufacturers will continue to have the option to use an alternative certification test fuel provided there is sufficient evidence indicating that this test fuel will be the predominant in-use fuel.

G. CALIBRATION AND SAMPLING TECHNIQUES

The proposal includes amendments to the test procedures adopted in the U.S. EPA's 2007 Final Rule that improve the precision of emission measurements. There are three general changes to the emission measurement requirements. One change involves the type of PM filters that are used, improvements to the method of weighing PM filters, and requirements for more precise microbalances. Another change is an allowance for lower dilution ratios during emission measurements, which improves the measurement of both gaseous and particulate emissions. The final change is the adoption of a new NOx calibration procedure that provides more precise and continuous measurements of low concentrations of NOx. An additional allowance is also proposed to provide manufacturers the option of using their current test procedures if they are more convenient or cost-effective in the short term. However, the ARB may conduct tests to confirm the results of any manufacturer testing to confirm the validity of the results.

H. AVERAGING, BANKING, AND TRADING PROGRAM

Manufacturers will continue to be allowed to certify engine families such that the aggregate average does not exceed the emission standard. Additionally, manufacturers may bank excess emission credits for later use or trade these credits to other manufacturers. Credits will continue to be based on the difference between the emission standard and the FEL. During the phase-in implementation of the proposed NOx emission standard, engines are classified as either “phased-out” or “phased-in.” The phased-out engines would meet the previously adopted 2.5 gram per brake horsepower-hour NOx plus NMHC emission standard. The phased-in engines would meet the proposed 0.2 gram per brake horsepower-hour NOx emission standard. NOx plus NMHC credits generated from phased-out engines may be used for NOx credit deficits from phased-in engines. However, NOx plus NMHC credits from phased-out engines will be subject to a 20% discount when converted to NOx only credits for phased-in engines.

Similar to the U.S. EPA’s 2007 Final Rule, averaging is proposed to be allowed between different weight class averaging sets. For example, emissions from heavy heavy-duty diesel engines may be averaged with emissions from medium heavy-duty diesel engines. This flexibility will only be allowed during the phase-in period, from the 2007 through 2009 model years. Comments have been received that the three model year averaging provision adopted in the U.S. EPA’s 2007 Final Rule may put manufacturers of medium heavy-duty diesel engines at a competitive disadvantage to manufacturers of both heavy and medium heavy-duty diesel engines. However, staff is not aware of any strong evidence that would support a “competitive disadvantage” argument, but rather that this three-year provision will provide manufacturers greater flexibility to introduce new technologies into the marketplace.

To be included in the ABT program, engine families must not exceed the proposed FELs. For phased-in engines subject to the 0.2 gram per brake horsepower-hour emission standard during the 2007 through 2009 model years, the proposed maximum NOx FEL cap is 2.00 grams per brake horsepower-hour. After all engines have been phased-in for the 2010 and subsequent model years, the proposed maximum NOx FEL cap is 0.50 grams per brake horsepower-hour. The proposed maximum PM FEL cap is 0.02 grams per brake horsepower-hour for all engines beginning in the 2007 model year.

I. EARLY INTRODUCTION OF LOWER EMITTING ENGINES

Identical to the U.S. EPA’s 2007 Final Rule, the proposal provides incentives for early introduction of lower emitting engines. Engines that satisfy the proposed requirements and are introduced into the marketplace, prior to 2007, will receive credits equal to 1.5 times the number of diesel-cycle engines that are introduced early. For example, two early introduction engines will reduce the number of required phased-in engines by three. Each early engine must meet all requirements applicable to model year 2007 engines. If the engine only complies with the PM requirements, the offsets may only be used for PM compliant engine credits.

Engines that can meet one half of the proposed NOx emission standard, or 0.10 grams per brake horsepower-hour, earlier than the phase-in period in addition to all other requirements applicable to model year 2007 engines will be classified as “Blue Sky Series” engines. These engines will receive a credit of 2.0 times the number of “Blue Sky Series” engines. For example, two “Blue Sky Series” engines will reduce the number of required phased-in engines by four.

Both early introduction programs detailed above will be based on U.S.-directed production.

V. DIFFERENCES AND SIMILARITIES BETWEEN FEDERAL AND CALIFORNIA REGULATIONS

The proposed emission standards and revised supplemental test procedures are intended to be identical to those adopted by the U.S. EPA in January 2001. This would reduce emissions from a group of vehicles that contribute greatly to California's emission inventory and would harmonize both California and federal requirements for HDDEs. Therefore, HDDE class applicability, emission standards, phase-in schedule, supplemental test procedures, the ABT program, and improvements to the calibration and sampling techniques are all identical to those adopted by the U.S. EPA in their 2007 Final Rule. The only differences from the federal rule are detailed below.

A. APPLICABILITY

The U.S. EPA adopted requirements applicable to both heavy-duty spark-ignited engines and heavy-duty diesel-cycle engines. Staff's proposal is only applicable to HDDEs and (all) MDDEs. Similar heavy-duty spark-ignited engine requirements will be considered in 2002.

B. ARB MEDIUM-DUTY EMISSION STANDARDS

The U.S. EPA's 2007 Final Rule includes emission standards for NOx, NMHC, PM, and CO for both MDDEs and HDDEs. The staff's proposal is identical with the exception that it also includes a formaldehyde standard (0.05 grams per brake horsepower-hour) for MDDEs. This is because this standard is already in place for MDDEs in California. Thus, the proposal only seeks to maintain this emission standard.

C. URBAN BUS EMISSION STANDARDS

The U.S. EPA's requirements for heavy-duty engine and vehicles include applicability to urban buses. Although the staff's proposal applies to both HDDEs and MDDEs, the proposal is not applicable to urban buses. Urban bus requirements were previously adopted by the Board in February 2000.

D. DIESEL FUEL REQUIREMENTS

The U.S. EPA's 2007 Final Rule includes requirements for low sulfur, in-use diesel fuel (less than 15 ppm sulfur by weight) and the phase-in of that fuel. Although the ARB is not including the in-use diesel fuel requirements with this proposal, the low sulfur diesel fuel is necessary to comply with the proposed emission standards (further described in Section VI below). As mentioned previously, ARB staff plans to propose low-sulfur in-use diesel fuel requirements to the Board in 2002. In the case that low sulfur, in-use diesel fuel requirements are not proposed and adopted by the ARB, the default fuel will be the same as that adopted by the U.S. EPA in their 2007 Final Rule.

E. PROPOSED FINDING

Section 209 of the federal Clean Air Act and Division 26, Part 5, Chapter 2 of California's Health & Safety Code provide the authority for California and the ARB, respectively, to establish and maintain its own new motor vehicle emissions certification and related enforcement programs. This authority reflects California's unique air quality problems and resulting need for flexibility to implement programs that may or may not mirror federal controls.

While continuing to maintain a separate program for these engines, throughout this ISOR staff has referred to its efforts to avoid conflicts with applicable federal regulations. Indeed, this proposal would adopt nearly identical requirements for California. And as detailed in Section IX of this ISOR, this proposal will not increase and may actually decrease costs of producing engines for the California market.

Therefore, to the extent this regulatory proposal has any differences from adopted federal regulations, such differences are both authorized by law and are justified by ARB's ongoing program to benefit human health and the environment.

VI. TECHNOLOGICAL FEASIBILITY

A. GENERAL REVIEW

Previous tightening of HDDE emission standards has primarily resulted in modifications to engine and combustion related components. Engine modifications included such changes as improved electronic controls, improved turbocharger systems, and improved exhaust gas recirculation. Combustion modifications included such changes as improved engine timing, improved fuel injection systems, and improved cylinder design. These types of technological changes continue, as documented in ongoing demonstration programs and scientific and engineering publications. However, to reduce emissions significantly further, other methods of control must be examined and utilized.

The U.S. EPA's 2007 Final Rule discusses the technological progress that has been made to further reduce emissions from HDDEs. This progress has primarily related to the use of aftertreatment systems. Compared to passenger cars, aftertreatment systems are a relatively new technology for HDDEs. However, throughout the United States and Europe there are ongoing demonstration programs evaluating the effectiveness of the aftertreatment systems. A majority of these programs have proven that aftertreatment systems are technically feasible. Further support for these systems is included in scientific and engineering publications. These aftertreatment-based emission control technologies are capable of reducing NOx, PM, and HC emissions.

One key to the durability of aftertreatment-based systems is the sulfur content of the diesel fuel. In general, lower fuel sulfur content allows longer aftertreatment system life and greater control efficiency. Specifically, sulfur adversely impacts the emission reducing capability of the aftertreatment device by attaching to the chemical sites that are needed for the catalytic reaction that reduces the emissions. Currently, California limits the sulfur level of diesel fuel used in on-road vehicles to 500 ppm. Actual average sulfur levels are about 120 ppm, less than one-quarter of the maximum limit. Currently, the U.S. EPA also limits sulfur levels of diesel fuel for on-road vehicles to 500 ppm with the average national, in-use sulfur level of 350 ppm. For manufacturers to take advantage of the emissions reduction potential of aftertreatment technologies, use of diesel fuel with a sulfur limit of 15 ppm or less will be necessary. Part of the U.S. EPA's 2007 Final Rule includes introduction of diesel fuel with 15 ppm sulfur content beginning in 2006. The ARB intends on proposing similar in-use diesel fuel requirements in 2002. If these in-use fuel requirements are not adopted by the ARB, in-use diesel fuel in California will at least meet the federal requirements. This will ensure that lower sulfur in-use diesel fuel is available for the aftertreatment systems described below.

In the next section below, overviews of various control technologies are included.

The first four control technologies are existing methods of control used to reduce emissions to current emission standards and test procedures. The last four control technologies are the specific aftertreatment systems that are expected to be used to comply with the emission standards in this proposal. Although details of each technology are somewhat brief, further discussion of the technologies can be found in the Regulatory Impact Analyses for both the U.S. EPA's 2004 and 2007 Final Rules. More extensive research references can be found in both aforementioned documents. In addition to the review of the U.S. EPA's Regulatory Impact Analysis for their 2007 Final Rule, ARB staff also reviewed on-going research and demonstration projects conducted by various government and industry groups. Review of current data has shown that the proposed requirements are technically feasible in the proposed time frame.

B. EXAMPLES OF TECHNOLOGY

1. *Exhaust Gas Recirculation*

Exhaust gas recirculation (EGR) operates by returning a portion of the exhaust gas back into the engine's combustion chamber. The recirculated exhaust gas reduces peak combustion temperatures by absorbing some of the combustion heat. Since NOx is formed as a result of high combustion temperatures and EGR reduces the combustion temperature, NOx emissions are reduced. The lower combustion temperature also reduces combustion efficiency and consequently, increases PM. However, PM increases can be minimized by controlling the amount of exhaust gas that is recirculated.

In addition to the increased PM emissions, another concern is that particulate soot from the recirculated exhaust may increase engine wear, damage a turbocharger, or reduce the efficiency of an aftercooler. Development is ongoing to reduce the particulate soot being recirculated back into the engine. Additional development continues to optimize the correlation between exhaust gas recirculation rate and combustion efficiency. HDDEs using EGR to meet the NOx plus NMHC emission standard of 2.4 grams per brake horsepower-hour, are expected to be offered for sale by mid-2002.

2. *Turbocharging and Aftercooling*

Turbochargers are used to increase power from a given engine size, or displacement. Exhaust gas is used to drive a turbine, which in turn increases the pressure of the engine's inlet air. With more air being forced into the combustion chamber, more fuel can be added. This results in higher power while large particulate formation is prevented. Since the mass emissions remain the same, increasing power from an engine decreases the brake specific emission rate.

Current turbocharger development efforts are focused on the use of variable geometry turbochargers. These turbochargers can increase or decrease the boost pressure depending on the operating conditions of the engine. Consequently, power, fuel consumption, and brake specific emission rate can be optimized.

Aftercooling was initially developed to increase the power of an engine by increasing the density of air entering the combustion chamber. This is of particular importance when turbochargers are used since, due to basic thermodynamic principles, the increase in pressure is accompanied by an increase in temperature, resulting in decreased air density. A positive side effect of aftercooling is that NOx emissions are reduced due to the reduced combustion temperature. There are two methods of aftercooling: air-to-water, which releases the heat from the inlet air to the engine coolant system; and air-to-air, which releases the heat directly to the ambient air.

3. *Timing Retard*

Timing retard is an adjustment to the engine that changes the time when fuel is injected into the engine's cylinder. This can reduce NOx emissions by reducing the time available for combustion and lowering the cylinder's temperature and pressure. However, this same action increases HC, CO, PM, and fuel consumption. In most cases, timing retard will be used with other control equipment and/or strategies to offset any emission increases that may occur.

4. *Advanced Fuel Injection Controls*

The fuel injection system is an important component of a compression-ignition (diesel) engine. By injecting fuel at higher pressure, fuel atomization and mixing with air is optimized. As a result, there is more complete combustion within the combustion chamber. Another method of fuel injection modification is through fuel injection rate shaping. Fuel is injected at different rates and times near the combustion event. Typically, fuel is injected pre- and post-combustion to ensure complete combustion of the fuel. Fuel injection is maintained with electronic controls and improved valves. The control of the combustion event minimizes any rapid increases in temperature and pressure and reduces NOx formation. Ongoing development is expected to result in additional NOx reductions from these advanced fuel injection controls.

5. *Crankcase Filtration/Ventilation*

Most analyses of diesel engine emissions only account for emissions in the exhaust. The crankcase of a diesel engine is also responsible for emitting NOx, NMHC, and PM. In the U.S. EPA's Regulatory Impact Analysis for the 2007 Final Rule, crankcase emissions are estimated to account for over 100 pounds of NOx, NMHC, and PM over the 30-year lifetime of the engine. To date, control of crankcase emissions has been required in all diesel engines except for those equipped with turbochargers. The premise for this exemption was that the particulate soot and engine oil from the crankcase would damage the turbocharger and/or aftercooler if those emissions were recirculated (similar to the use of EGR).

Technology in the control of crankcase emissions has improved. Two primary methods of control are closed crankcase filter systems and transfer of the crankcase gases to the exhaust system prior to the aftertreatment control system. A closed crankcase filtration system operates by routing the crankcase gases through a filter. The filtered oil is returned to the oil sump while the filtered crankcase gases are returned to the engine's intake manifold. Closed crankcase filtration systems have been in use for several years in stationary source applications. Although these systems must be adapted for on-road applications, the technology has been demonstrated. Transfer of the crankcase gases to the exhaust is a method of control that does not require much additional technology. Since these gases are transferred prior to the aftertreatment system, control of the gases is completed with all the other exhaust. A concern for this method of control may be the potentially high sulfur content in the crankcase oil. Similar to a high sulfur content in the fuel, high sulfur content in the crankcase oil also has the potential to damage certain aftertreatment control devices.

6. *Diesel Particulate Filters*

Diesel particulate filters are primarily used to reduce PM emissions. The filter typically consist of a ceramic substrate that filters, or traps, the exhaust. Eventually, particulate filters require some periodic "cleansing" by either reversing the direction of the exhaust flow, or cleaning the filter in a liquid. Particulate filters may also be "regenerated" to prolong their effective use by burning the trapped PM. There are two methods of regeneration: active and passive. Active regeneration utilizes an external device or event to actively regenerate the filter. The use of external heating elements is an example of an active regeneration method where the heating elements periodically raise the temperature of the filter to burn the trapped PM. A passive regeneration system typically uses filters that are coated with a catalyst material. The catalyst provides a catalytic reaction to lower the combustion temperature required to burn the trapped PM. Consequently, exhaust temperatures normally occurring in MDDEs and HDDEs are suitable to burn most of the PM emissions. Further, there is also a reduction in hydrocarbon emissions.

A variation to the catalyzed particulate filter is the use of fuel borne catalysts. Rather than coating the filter with the catalyst, a small percentage of catalyst solution is mixed into the fuel. Since the catalyst is present in the combustion chamber, the catalyst also immediately becomes a component of the exhaust and the catalytic reaction begins earlier. By using the fuel borne catalyst in conjunction with the catalyzed diesel particulate filter a better reduction of PM emissions compared to use of a catalyzed diesel particulate filter alone.

Diesel particulate filters have been proven successful in a variety of worldwide applications and demonstration programs. Though some failures have occurred, they mainly involved later model engines and engines using diesel fuel with a high sulfur content. For catalyzed particulate traps, high fuel sulfur content results in high levels of sulfate-based PM, making low “tail pipe” PM levels infeasible. Recent tests using diesel particulate filters have demonstrated a reduction of PM emissions by 90 percent and more.

7. *Lean-NOx Catalysts*

A lean-NOx catalyst operates similarly to the catalyzed diesel particulate filter. However, fuel is injected in the exhaust stream after the combustion chamber, upstream of the lean-NOx catalyst. With the catalyzed filter, the additional hydrocarbons (in the form of diesel fuel) initiate the reduction of NOx. There are typically two types of lean-NOx catalysts, each with different catalyst formulations. One catalyst formulation is used to operate in the high exhaust temperature range, while the other catalyst formulation is used to operate in the low exhaust temperature range. Since the lean-NOx catalyst utilizes fuel injection, the excess fuel in the exhaust can also be used to regenerate a diesel particulate filter.

Although technical improvements and testing are ongoing, recent tests of the lean-NOx catalysts have shown NOx reductions between 30 percent and 40 percent. The proposed emission standards will require an approximate 90 percent reduction of NOx emissions. Therefore, it is expected that this catalyst may be used in combination with other control strategies.

8. *NOx Adsorbers*

Basic operation of a NOx adsorber stores NOx and releases nitrogen and carbon dioxide. The engine must cycle between fuel lean and fuel rich conditions to reduce NOx emissions. Fuel lean conditions, typical of diesel-cycle operation, occur when less than the stoichiometrically required fuel is injected into the combustion chamber. This results in lower exhaust temperatures. "Trapping" of NOx emissions occurs during fuel lean operating conditions, when NOx is converted to inorganic nitrates ($-NO_3$) and is adsorbed onto a catalyst material.

Fuel rich conditions occur when more than the stoichiometrically required fuel is injected into the combustion chamber prior to combustion. This results in higher exhaust temperatures and additional hydrocarbons (fuel) in the exhaust. Regeneration occurs during fuel rich operating conditions, when the elevated temperatures reduce the trapped, or adsorbed, nitrate compounds. As stated above, the nitrate reduction generally results in the formation of nitrogen and carbon dioxide.

Research and demonstrations of this technology are ongoing. Current testing has shown NOx reductions of at least 90%.[24] However, NOx adsorbers are extremely sensitive to the sulfur content in the diesel fuel. The resulting oxides of sulfur emissions more readily react with the catalyst material. This slowly degrades the ability of the catalyst to adsorb NOx emissions. Further, the resulting sulfate compounds are more stable than the nitrate compounds on the catalyst. Therefore, removal of the sulfate compounds to regenerate the catalyst is more difficult.

9. *Selective Catalytic Reduction (SCR)*

SCR technology has been used for many years in stationary source applications, particularly with power plants, and has been recently applied to mobile source applications. SCR typically utilizes ammonia to selectively reduce NOx as the exhaust passes through a catalyst substrate. Due to adverse health effects, ammonia is typically stored on-board the vehicle as an aqueous urea solution and injected separately into the exhaust stream. Depending upon the formulation of the catalyst, an SCR system may be sensitive to sulfur.

One concern with the injection of ammonia into the exhaust stream is that the injection rate has to be precise and constantly monitored. If the injection rate is too low, the amount of NOx control efficiency is reduced. If the injection rate is too high, excess ammonia is released (also known as "ammonia slip"). This can pose a

[24] See Diesel Emission Control - Sulfur Effects program "Phase II Summary Report: NOx Adsorber Catalysts", October 2000.

health concern in urban areas where population is dense. Another concern is the maintenance and distribution of urea. A control system is necessary to ensure urea levels in the vehicle are sufficient at all times, similar to a fuel indicator lamp. Additionally, there is no current distribution system or infrastructure in place to ensure a sufficient supply of urea to the public.

Despite these concerns, research and demonstration of SCR is ongoing. SCR has demonstrated[25] average NOx reductions of 70 percent using 230 ppm sulfur content diesel fuel[26].

10. *HC and H2S Clean-up Catalyst*

NOx adsorber performance can deteriorate due to the sulfur in the diesel fuel with sulfur contents as low as 3 ppm.[27] To increase the durability of the NOx adsorber, a sulfur regeneration event, or desulfation event, is required. Byproducts of this desulfation event are hydrogen sulfide (H_2S) and sulfur dioxide (SO_2). Hydrogen sulfide is an unwanted byproduct since, at even low concentrations, this gas has a strong, undesirable odor. Therefore, clean-up catalysts are expected to be utilized downstream of the NOx adsorber. The clean-up catalyst operates similar to a NOx adsorber by storing hydrogen sulfide during fuel "lean" conditions, and oxidize the hydrogen sulfide during fuel "rich" conditions. When hydrogen sulfide is oxidized, the resulting byproducts would be sulfur dioxide and water. Typically, the catalyst would consist of nickel oxide formulation. Therefore, except for the catalyst formulation, the design of the clean-up catalyst is identical to the NOx adsorber.

[25] SAE 2001-01-0514.

[26] Similar to other catalyst based control systems, the sulfur in the diesel exhaust reduces the NOx control efficiency and degrades the ability of the catalyst to reduce NOx emissions.

[27] Also see the U.S. EPA's Regulatory Impact Analysis for their 2007 Final Rule.

VII. REMAINING ISSUES

Most of the catalyst-based emission control systems that are likely to be used to comply with the 2007 emission standards are highly sensitive to the diesel fuel sulfur content. Consequently, when the U.S. EPA adopted their 2007 Final Rule in January 2001, they included requirements for lower sulfur diesel fuel with a maximum fuel sulfur content of 15 ppm. Although there are no in-use diesel fuel sulfur requirements included in this proposal, lower in-use diesel fuel sulfur content requirements are planned for consideration in 2002. Federal adoption of low sulfur diesel fuel requirements provides a backstop to ensure in-use fuel availability for the various aftertreatment control systems. Further, fuel specifications have been proposed for emission testing and service accumulation.

Manufacturers and organizations have voiced concern that the U.S. EPA's 2007 Final Rule applies to urban transit buses, while the ARB's proposal excludes urban transit buses. Of particular concern is that the ARB's existing NMHC and CO emission standards for transit buses are significantly lower (by almost two-thirds) than the U.S. EPA's adopted emission standards and that the ARB's existing emission standard phase-in is more aggressive. The ARB staff is not planning to revise its existing emission standards and phase-in for urban transit buses at this time. There is concern over the potential adverse impact of relaxing emission standards for urban bus engines that typically operate in highly populated areas. Additionally, there is sufficient lead time to review technology development for urban bus engines at a later date.

Of additional concern to engine manufacturers has been the current state of aftertreatment technology. Current testing of the various types of control systems by the U.S. EPA[28] has shown that the systems are capable of complying with the proposed requirements. However, while diesel particulate filters have been demonstrated to be durable in a variety of applications, engine manufacturers would argue that the other aftertreatment based technologies previously discussed have limited in-field experience. While this may be true, staff believes that in-field experience is only needed to explore and/or uncover any unforeseen technical challenges one might observe with varying vehicle applications and operating conditions. That is, the staff does not believe there are any issues with regard to performance capabilities of any of the aftertreatment-based technologies described previously. Thus, to address any technical challenges, staff plans to carefully track in-field demonstration projects and expects engine manufacturers to complete more extensive on-road testing compared to previous years. Further, engine manufacturers have over 5 years of lead time to refine their emission reduction strategies and technologies. Engine manufacturers involved in the California settlement agreements have shown that less time is necessary to develop engine technology to comply with reduced emission standards. In addition, the ABT provisions included in the proposal will provide additional flexibility for the engine manufacturers.

[28] See the Regulatory Impact Analysis for the 2007 Final Rule for more details.

VIII. REGULATORY ALTERNATIVES

The staff evaluated various alternatives to the proposed amendments. A brief description of the alternatives and the staff's reasoning for rejecting them follows.

A. DO NOT AMEND CURRENT CALIFORNIA REGULATIONS

One alternative to this proposal would be to continue using the current on-road heavy-duty diesel emission standards and test procedures for 2004 and subsequent model years. The current emission standards are 10 times greater for NOx and PM emissions and over 3 times greater for NMHC emissions as compared to the proposed emission standards. Consequently, the current requirements will allow engines to emit more during the same time period. The current emission standards will result in excess emissions in California from HDDEs of approximately 40 tons per day of NOx, 2 tons per day of PM, and 1 ton per day of ROG in 2010. Because of these potential emissions, and because the technologies needed to achieve the reductions have been demonstrated, staff rejected this alternative.

B. ADOPT MORE STRINGENT EMISSION STANDARDS

The staff recognizes that emission standards for the control of emissions from HDDEs more stringent than those in this proposal may be necessary to attain ambient air quality standards for ozone and particulate matter. Emission benefits of this proposal are discussed in Section X. However, the current state of technological development has only demonstrated reductions equivalent to the reductions being proposed. Therefore, at this time, staff is not recommending more stringent requirements compared to those adopted by the U.S. EPA in their 2007 Final Rule.

IX. ECONOMIC IMPACTS

The proposed emission standards and supplemental test procedures are essentially identical to those adopted by the U.S. EPA for 2007 and subsequent model year HDDEs in their 2007 Final Rule. Adoption of the proposed emission standards and supplemental test procedures would not impose additional costs above the costs to comply with the requirements set forth in the U. S. EPA's 2007 Final Rule.

Staff believes that the proposed emission standards and supplemental test procedures will not impose additional costs on the engine and vehicle manufacturers since they will have to meet the identical requirements nationwide in the same time period. The proposed adoption of the emission standards and supplemental test procedures is expected to have no noticeable impact on California business competitiveness, employment, or on business creation, elimination, and expansion beginning in 2007. A detailed discussion of the potential cost and economic impacts of the proposed amendments follows, based primarily on the U.S. EPA's 2007 Final Rule.

A. LEGAL REQUIREMENT

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment includes a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any non-discretionary cost or savings to local agencies and the cost or savings in federal funding to the State.

B. AFFECTED BUSINESSES

Any business that is involved in manufacturing on-road HDDEs and MDDEs may be affected by the proposed emission standards and supplemental test procedure modifications. ARB has identified 21 major engine manufacturers worldwide. Based on California's emission inventory model, EMFAC2000 Version 2.0, a projected total of 464,000 and 488,000 on-road medium heavy-duty[29] and heavy heavy-duty diesel engines will be operating in California in 2007 and 2010, respectively. Projections indicate that approximately 12,000 new, medium-duty and heavy-duty diesel vehicles may be affected each model year from 2007 through 2009, and 24,000 beginning in the 2010 model year.

[29] Including school buses and motor homes.

Since the proposed requirements harmonize requirements with the U.S. EPA in their 2007 Final Rule, there may be a net decrease in engine and vehicle costs to the consumers. The decrease in costs is expected due to the consolidation of engine manufacturing lines.

The U.S. EPA's adopted emission standards and supplemental test procedures may require additional or upgraded engine accessories. As a result, the HDDEs meeting the U.S. EPA adopted standards may be more costly to manufacture, and hence heavy-duty vehicles may cost more nationwide. However, this will not put California businesses at a disadvantage since similar costs will be incurred by businesses in other states. The baseline average costs for a heavy-duty diesel engine, vehicle, and the operating costs based on a 30-year lifetime are shown in Table 11, with potential nationwide increases shown in Table 12.

Table 11 - Baseline Heavy-Duty Engine and Vehicle Costs

Heavy-Duty Class	Engine Cost	Vehicle Cost	Operating Cost
Light Heavy-Duty	$ 8,995.00	$ 25,952.00	$ 14,357.00
Medium Heavy-Duty	$ 14,300.00	$ 53,199.00	$ 36,028.00
Heavy Heavy-Duty	$ 25,024.00	$111,272.00	$124,577.00

Source: U.S. EPA's Final Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000. Costs are in year 2001 dollars.

Table 12 - Potential Nationwide Cost Increases for Transportation Businesses

Heavy-Duty Class	Increased Engine and Vehicle Cost (2007)	Increased Annual Operating Cost[30]	Total Annualized Cost (20 year) [31]
Light Heavy-Duty	$ 2,095.00	$ 43.36	$ 241.11
Medium Heavy-Duty	$ 2,705.00	$ 80.10	$ 335.44
Heavy Heavy-Duty	$ 3,405.00	$ 321.78	$ 643.19

Source: U.S. EPA's Final Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000. Costs are in year 2001 dollars.

Light and medium heavy-duty vehicles are assumed (from the EMFAC 2000 emissions inventory model) to only operate within the State. The net impact of

[30] These costs include low sulfur diesel fuel costs and the associated decrease in maintenance costs due to use of low sulfur diesel fuel.
[31] These costs include low sulfur diesel fuel costs and the associated decrease in maintenance costs due to use of low sulfur diesel fuel.

increasing vehicle and operating costs will not increase competition from transportation companies that register their vehicles outside of California since these costs will be incurred by companies from other states. However, the harmonization of California and federal requirements may actually improve manufacturing efficiency due to the consolidation of various engine manufacturing lines, therefore benefiting California businesses.

C. ESTIMATED COSTS TO ENGINE MANUFACTURERS

Since the proposed emission standards and supplemental test procedures are identical to those adopted by the U.S. EPA in their 2007 Final Rule, there is no increase in costs for engine manufacturers to produce California HDDEs. There may actually be a decrease in costs since engine manufacturers only need to produce a single line of clean engines. However, costs presented here examine the potential increase in engine costs due to the U.S. EPA's 2007 Final Rule. These costs are provided for information only as they are not attributable to the amendments and California emission standards proposed herein.

Costs have been estimated and are based on U.S. EPA's analysis for their 2007 Final Rule. The U.S. EPA's analysis includes not only costs to comply with identical emission standards and supplemental test procedures, but also costs for using low sulfur diesel fuel.[32] All engine manufacturers are assumed to utilize multiple technologies to satisfy the proposed requirements for 2007 and subsequent model year medium- and heavy-duty engines. The technologies that are assumed to be used, include a NOx adsorber system, a catalyzed diesel particulate filter (DPF), a hydrocarbon (HC) and hydrogen sulfide (H_2S) clean-up catalyst, a closed crankcase system, and low sulfur diesel fuel. Additionally, there is an expected savings in maintenance costs due to the use of low sulfur diesel fuel. These costs are included since, at this time, the assumed technologies require the use of low sulfur diesel fuel (see Section VI, above). Using the assumed technologies results in the most conservative cost estimate[33] since manufacturers will likely use several of the technologies, in addition to averaged and banked emission credits, and does not account for improvements in technology. Assuming that engine manufacturers pass on the entire costs of the new federal requirements to the end users, the incremental increase in per-engine price and overall lifetime operating costs have been estimated. These cost estimates are presented in Table 13 and are identical to those determined by the U.S. EPA.

[32] Low sulfur diesel fuel includes diesel fuel with a sulfur content of 15 parts per million or less. Low sulfur diesel fuel requirements have been adopted federally in the 2007 Final Rule will be included in a separate California proposal.
[33] i.e., assuming highest costs per engine.

Table 13 - Projected Additional Unit Costs per Engine

Light Heavy Heavy-Duty (8,501 – 14,000 lbs. GVWR) Item	Fixed Cost	Variable Cost	30 yr NPV Operating Cost[34]
NOx Adsorber System	$ 87.00	$ 925.00	$ 0.00
Catalyzed DPF	$ 41.00	$ 690.00	$ 55.00
HC and H2S Clean-up Catalyst	$ 0.00	$ 206.00	$ 0.00
Closed Crankcase System	$ 0.00	$ 37.00	$ 31.00
Low Sulfur Diesel Fuel	$ 0.00	$ 0.00	$ 576.00
Maintenance Savings	$ 0.00	$ 0.00	$ (153.00)
TOTAL	$ 128.00	$ 1,858.00	$ 509.00
Medium Heavy-Duty (14,001 – 33,000 lbs. GVWR) Item	Fixed Cost	Variable Cost	30 yr NPV Operating Cost[28]
NOx Adsorber System	$ 231.00	$ 1,080.00	$ 0.00
Catalyzed DPF	$ 98.00	$ 852.00	$ 56.00
HC and H2S Clean-up Catalyst	$ 0.00	$ 261.00	$ 0.00
Closed Crankcase System	$ 0.00	$ 42.00	$ 59.00
Low Sulfur Diesel Fuel	$ 0.00	$ 0.00	$ 1,077.00
Maintenance Savings	$ 0.00	$ 0.00	$(249.00)
TOTAL	$ 329.00	$ 2,235.00	$ 943.00
Heavy Heavy-Duty (33,001 lbs. and greater GVWR) Item	Fixed Cost	Variable Cost	30 yr NPV Operating Cost[28]
NOx Adsorber System	$ 191.00	$ 1,456.00	$ 0.00
Catalyzed DPF	$ 89.00	$ 1,103.00	$ 208.00
HC and H2S Clean-up Catalyst	$ 0.00	$ 338.00	$ 0.00
Closed Crankcase System	$ 0.00	$ 49.00	$ 218.00
Low Sulfur Diesel Fuel	$ 0.00	$ 0.00	$ 3,969.00
Maintenance Savings	$ 0.00	$ 0.00	$ (610.00)
TOTAL	$ 280.00	$ 2,946.00	$ 3,785.00

Source: U.S. EPA's Final Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000. Costs are in year 2001 dollars.

The estimated costs are separated into incremental engine purchase price and annual operating costs. The incremental engine purchase price for new engines includes the fixed and variable costs. Fixed costs are costs associated with

[34] Costs shown in parenthesis are negative costs, or cost savings.

research and development, retooling, and certification. Variable costs are costs associated with hardware and assembly. Annual operating costs include any expected increases in maintenance and/or fuel consumption. U.S. EPA relied on two studies of the economic impacts on heavy-duty highway engines. One study is by ICF Consulting[35] and the other study is by Engine, Fuel, and Emissions Engineering.[36] All costs in the ICF Consulting and Engine, Fuel, and Emissions Engineering studies were presented in 1999 dollars, although the costs shown in the table above are in 2001 dollars.

These estimated costs are expected to decrease over time due to decreased costs for mass production. However, using the conservative costs shown above and an annual discount rate of 7.0 percent, the resulting lifetime costs per engine represented as net present value are detailed in Table 14, below.

Table 14 - Projected Lifetime Net Present Value Cost Increase per Engine

	Lifetime NPV Cost
Light Heavy-Duty	$ 2,554.31
Medium Heavy-Duty	$ 3,553.61
Heavy Heavy-Duty	$ 6,813.96
Weighted Average of All Heavy-Duty	*$ 4,221.02*

D. POTENTIAL COSTS TO VEHICLE MANUFACTURERS

Since the proposed emission standards and supplemental test procedures are identical to those adopted by the U.S. EPA in their 2007 Final Rule, there is no expected increase in costs to engine and vehicle manufacturers attributable solely to the amendments proposed herein. There may actually be a decrease in costs since the engine and vehicle manufacturers will not be required to produce multiple lines of engines and vehicles.

E. POTENTIAL IMPACTS ON BUSINESS

There are no known potential impacts on businesses other than the additional costs for the engines and the additional annual operating costs, both described above. These costs, however, are a result of the federal requirements in the 2007 Final Rule. By harmonizing federal and California requirements, engine manufacturers

[35] "Economic Analysis of Vehicle and Engine Changes Made Possible by the Reduction of Diesel Fuel Sulfur Content, Task 2 - Benefits for Durability and Reduced Maintenance," prepared by ICF Consulting for the U.S. EPA, December 9, 1999.
[36] "Economic Analysis of Vehicle and Engine Changes Made Possible by the Reduction of Diesel Fuel Sulfur Content," prepared by Engine, Fuel, and Emissions Engineering for the U.S. EPA, December 15, 1999.

will only be required to manufacture one line of clean engines. This is expected to result in lower costs due to more efficient manufacturing. The costs summarized by vehicle class and model year are detailed in Table 15, below.

Table 15 - Estimated Price and Cost Increases for New On-Road Diesel Vehicles (per vehicle)

	2007 MY	Operating Costs NPV (20 yr)	Annualized Total Cost
Light Heavy-Duty	$ 2,095.00	$ 459.31	$ 241.11
Medium Heavy-Duty	$ 2,705.00	$ 848.61	$ 335.44
Heavy Heavy-Duty	$ 3,405.00	$ 3,408.96	$ 643.19
Weighted Average of All Heavy-Duty	*$ 2,772.37*	*$ 1,441.89*	*$ 398.43*

Based on: U.S. EPA's Final Regulatory Impact Analysis: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, December 2000. Costs are in year 2001 dollars.

The costs shown above are only for engines that are phased in during the 2007 model year. Due to projected changes in purchasing, the weighted average costs will be slightly different (less than 1 percent) from year to year.

F. POTENTIAL IMPACT ON BUSINESS COMPETITIVENESS

The proposed amendments would have no significant impact on the ability of California businesses to compete with businesses in other states. This is because the proposed emission standards and test procedures are identical to those adopted by the U.S. EPA in their 2007 Final Rule. Therefore, any increase in costs due to federal requirements will also be experienced by non-California businesses. Further, all manufacturers that manufacture diesel engines for sale in California are subject to the proposed amendments regardless of where they are located and where the engines are planned for sale. Most manufacturers of diesel engine have no major manufacturing facilities in California.

California trucking companies, which use HDDEs, are not expected to experience any increase in the price of a new truck because of the proposed amendments, relative to those in other states. The federal amendments in the 2007 Final Rule are expected to increase the price of a new truck by about 3 to 8 percent compared to the estimated vehicle price of $26,000 for a light heavy-duty vehicle, $53,000 for a medium heavy-duty vehicle, and $111,000 for a heavy heavy-duty vehicle. Price increases of this magnitude are not expected to dampen the demand for heavy-duty trucks in California relative to other states, since price increases will be the same nationwide.

G. POTENTIAL IMPACT ON EMPLOYMENT

California accounts only for a small share of manufacturing employment for diesel engine production. According to the U.S. Department of Commerce, California employment in the internal combustion engines industry (NAICS 333618), which includes manufacturers of diesel engines, was 1,635 persons in 1998 or less than 0.1 percent of total manufacturing jobs in California. These employees work in 28 businesses across the state. One business employed over 500 people, two employed between 100 and 500, and the rest had less than 100 employees. Employment in these businesses is unlikely to be affected adversely because the price increase that would result from the implementation of federal standards nationwide are not attributable to the amendments proposed herein. Thus, the proposed amendments are not expected to cause a noticeable adverse impact on the California employment.

However, some jobs may be created in research and development to enhance the design of current engine models and develop additional systems to reduce emissions from HDDEs. Currently, engine manufacturers lack significant experience with aftertreatment systems expected to be used for compliance. This may result in additional jobs from developers and manufacturers of aftertreatment systems. Some jobs may also be created in businesses manufacturing and distributing parts related to the aftertreatment systems. Some of these jobs may be created in California.

H. POTENTIAL IMPACT ON BUSINESS CREATION, ELIMINATION OR EXPANSION

The proposed amendments would have no noticeable impact on the status of California businesses. The amendments would not impose additional costs on HDDE manufacturers. Adoption of the proposed amendments may actually reduce costs for HDDE manufacturers. We estimate the cost increase due to the U.S. EPA's 2007 Final Rule would range from about $2,095 to $3,405 per engine in the 2007 model year.[37] As noted above, the vehicle prices are expected to decrease with time due to reduced manufacturing costs. Since the costs will be applied nationwide, the proposal is not expected to alter the status of California businesses. The proposed amendments may actually result in creation or expansion of businesses that are engaged in manufacturing of aftertreatment systems and parts in California.

[37] Hardware costs only. Does not include operating cost increases and decreases.

I. POTENTIAL COSTS TO LOCAL AND STATE AGENCIES

The proposed amendments have no impact on the current budget and the budget for the next two fiscal years since the proposed requirements begin in the 2007 model year.

The proposed amendments will harmonize California requirements with federal requirements. Any increase in engine costs is due to compliance with federal requirements. Net costs may actually decrease because of improved manufacturing efficiency. We expect no additional costs for local and state agencies because there should be no price increase to end users attributable solely to the amendments proposed herein.

All implementation "costs" to the state as a result of this rulemaking should be costs to the ARB to implement the amendments. All implementation costs are expected to be negligible and absorbable within the existing ARB budget. The ARB currently enforces its heavy-duty emission standards by reviewing and acting upon applications for certification, and monitoring in-use compliance. These actions are currently completed by staff from ARB's Enforcement Division (ED), Mobile Source Control Division (MSCD), and Mobile Source Operations Division (MSOD). The amendments should not affect the number of models certified in California or the number of vehicles sold in the state.

X. ENVIRONMENTAL IMPACTS AND COST-EFFECTIVENESS

The air quality benefits and the cost-effectiveness of the proposed emission standards and revised supplemental test procedures are presented in this section. The analysis, though based on the U.S. EPA's Regulatory Impact Analysis for their 2007 Final Rule, is adjusted to reflect costs in California, emissions reduced in California, and the slight increase in CO emissions in California due to the alignment of the MDDE CO emission standard. Because of these adjustments, the presented cost-effectiveness for the proposed supplemental test procedures is conservative. Yet, because the proposed requirements would apply statewide, they would provide significant cost-effective emission reductions throughout California. Due to the proposed phase-in of the NOx emission standard, calendar years 2007 through 2009 are not included in statewide and regional emissions calculations. Since the proposed emission standards are identical to those adopted by the U.S. EPA in their 2007 Final Rule, all calculations include out-of-state vehicle emissions generated while operating within California. These emissions account for approximately 20 percent additional emissions within California.

A. AIR QUALITY BENEFITS

1. Statewide Benefits

Using the methodology described below, Table 16 shows emissions that would be reduced with the proposal statewide and in several California air basins that have not yet achieved National Ambient Air Quality Standards for the 2010, 2015, and 2020 calendar years. Over the lifetime of a typical phased-in vehicle from the 2007 and subsequent model years, the average amount of emissions reduced is 4.2 tons of NOx plus NMHC per vehicle and 0.1 tons of PM per vehicle. The slight increase in CO emissions will result in negligible emissions increased over the lifetime of the vehicle.

Table 16 - Emissions Reduced by Air Basin in 2010, 2015, and 2020 (tons per day)

	Calendar Year	Criteria Air Pollutant			
		NOx	ROG	PM	CO[38]
San Francisco Bay Area Air Basin	2010	6.4	0.2	0.4	0.0
	2015	17.1	0.7	0.8	0.0
	2020	24.9	1.1	1.1	(0.1)
Sacramento Valley Air Basin	2010	3.9	0.1	0.2	0.0
	2015	10.8	0.4	0.5	0.0
	2020	15.7	0.6	0.7	0.0
San Joaquin Valley Air Basin	2010	7.5	0.2	0.4	0.0
	2015	22.7	0.8	1.0	0.0
	2020	33.1	1.4	1.3	(0.1)
South Coast Air Basin	2010	24.3	0.9	1.2	0.0
	2015	68.5	2.4	2.8	(0.1)
	2020	105.1	4.1	4.0	(0.2)
Statewide	2010	48.0	1.5	2.7	(0.1)
	2015	140.0	5.1	5.9	(0.2)
	2020	209.5	8.5	8.3	(0.3)

As shown in Table 16, aligning California's emission standards for medium-duty diesel engines with the federal emission standards would result in a very small carbon monoxide increase, estimated to be about 0.1 tpd statewide in 2010. This increase is negligible when compared to total statewide carbon monoxide emissions of 13,000 tons per day (of which, about 100 tpd come from heavy-duty diesel trucks). Furthermore, the increase will not impact the overall declining trend in carbon monoxide emissions; between 2000 and 2010, statewide carbon monoxide emission are expected to drop by over 35 percent.

All of California, with the exception of Los Angeles County and Calexico in Imperial County, meets the ambient air quality standards for carbon monoxide. Localized strategies are being developed to bring the remaining areas into attainment. With the overall declining trend in emissions, the small CO impact of this regulation would not affect the prospects of Los Angeles and Calexico meeting the standard and the rest of the state maintaining the standard.

[38] Reduced CO emissions shown in parenthesis are negative reductions, or CO emission increases.

2. Methodology to Calculate Emission Reductions

The emission reductions are calculated for each air contaminant below using the ratio of the proposed emission standard and the pre-2007 emission standard (also known as the “2004 standard”). Each calculation yields the amount of emissions that would be reduced from the baseline emissions inventory.

ROG = 1 - (proposed standard / 2004 standard)
= 1 - (0.14 grams per brake horsepower-hour / 0.5 grams per brake horsepower-hour)
= 1 - 0.28
= 0.72 or 72% reduction

NOx = 1 - (proposed standard / 2004 standard)
= 1 - (2.0 grams per brake horsepower-hour / 0.2 grams per brake horsepower-hour)
= 1 - 0.1
= 0.90 or 90% reduction

PM = 1 - (proposed standard / 2004 standard)
= 1 - (0.1 grams per brake horsepower-hour / 0.01 grams per brake horsepower-hour)
= 1 - 0.1
= 0.90 or 90% reduction

CO = 1 - (proposed standard / 2004 standard)
= 1 - (15.5 grams per brake horsepower-hour / 14.4 grams per brake horsepower-hour)
= 1 – 1.08
= -0.08 or 8% increase

3. Impacts on the State Implementation Plan

The 1994 Ozone SIP is California’s plan for achieving the federal ozone standard in all areas of the state by the federally required date. For the South Coast Air Basin, the 1994 SIP requires that the federal ozone standard must be met by 2010. The SIP includes state measures to control emissions from motor vehicles and fuels, consumer products and pesticide usage, local measures for stationary and area sources, and federal measures for sources under exclusive or practical federal control. U.S. EPA approved the 1994 SIP in September 1996.

Once U.S. EPA approved the 1994 SIP (and the 1999 update for the South Coast), the emission inventories and assumptions used in the SIP are frozen. Evaluations of the impacts on the SIP of new measures or modifications to existing measures must use the same emission inventories and assumptions used in developing the SIP.

The Ozone SIP contains several measures to reduce emissions from heavy-duty diesel trucks. These include: (1) measure M4 – early introduction of cleaner engines, which is being implemented through the Carl Moyer Program; (2) measures M5 and M6 – 2 grams per brake horsepower-hour emission standard of NOx for new trucks in California and nationwide, which is already adopted by the ARB and the U.S. EPA; and (3) measure M17 – additional reductions from heavy-duty vehicles, which is on schedule to be adopted by 2004.

As ARB has implemented the SIP over the last seven years, some measures have delivered more reductions than anticipated, while other measures have delivered fewer reductions due to technical or economic concerns. In some cases, measures not originally envisioned in the 1994 SIP are providing benefits which will help meet the SIP emission reduction obligations.

The South Coast Air Quality Management District revised its part of the Ozone SIP in 1997 and again in 1999. These revisions focused on the measures under local jurisdiction and did not alter the state motor vehicle strategies with the exception of updating the emission inventory. (The motor vehicle emission inventory for the 1994 SIP was based on the EMFAC 7F model, while the South Coast's 1999 SIP revision was based on the EMFAC 7G model.) U.S. EPA approved the South Coast's 1999 Ozone SIP revision in April 2000.

Although the 2007 diesel truck standards were not originally including in the 1994 SIP, this proposal will provide emission reductions needed to help meet California's remaining SIP commitments including the South Coast's long-term "Black Box" commitments. The benefits of the proposal in the SIP inventory are provided in Table 17. Because the reductions do not take effect until 2007, we have quantified the benefits for the only area with a post-2007 attainment date – the South Coast.

Table 17 - South Coast Emission Reductions From Proposed 2007 Diesel Truck Standards (measured in inventory of approved 1999 South Coast Ozone SIP, tons per day)

Year	ROG	NOx
2010	0.7	15

The benefits of the proposal in the SIP inventory are smaller than those based on the latest inventory (about 15 tons per day NOx versus 24 tons per day in the South Coast in 2010 – see Table 17 for comparison). The SIP inventory contains fewer NOx emissions from trucks than the latest motor vehicle emission inventory that is based on the EMFAC 2000 model. Consequently, the corresponding NOx emission reductions from the 2007 emission standards are also less in the SIP inventory.

B. COST-EFFECTIVENESS

This proposal contains the most conservative cost estimates, as described in the sections above. The estimated cost of complying with the emission standards and supplemental test procedures will vary depending on the GVWR class.

As shown in Figure 2, the cost-effectiveness of California mobile source and motor vehicle fuels regulations adopted over the past decade range from $0.17 to $2.55 per pound of ozone precursors reduced. The cost-effectiveness of the proposed emission standards and revised supplemental test procedures by weight class is $0.29 per pound of NOx plus NMHC reduced for light heavy-duty vehicles, $0.63 per pound of NOx plus NMHC reduced for medium heavy-duty vehicles, and $0.32 per pound of NOx plus NMHC reduced for heavy heavy-duty vehicles. Combining the cost-effectiveness for all heavy-duty vehicles based on predicted sales, results in $0.42 per pound of NOx plus NMHC reduced for all heavy-duty vehicles (identified with a X marker on Figure 4).

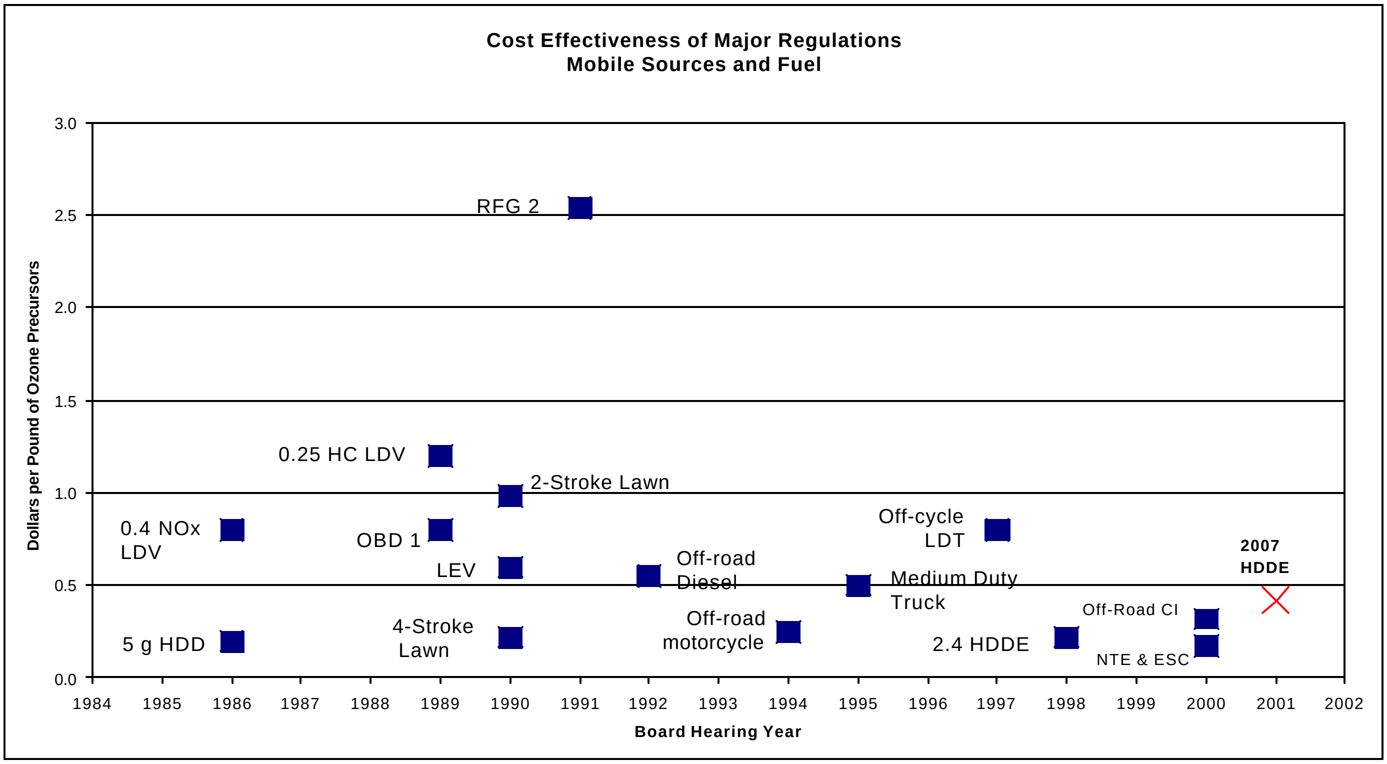


Figure 4

Cost-effectiveness is also calculated for the reductions of PM emissions. The cost-effectiveness by weight class is $6.65 per pound of PM reduced for light heavy-duty vehicles, $3.45 per pound of PM reduced for medium heavy-duty vehicles, and $3.03 per pound of PM reduced for heavy heavy-duty vehicles. Combining the cost-effectiveness for all heavy-duty vehicles based on predicted sales, results in $3.42 per pound of PM reduced for all heavy-duty vehicles. Although PM cost-effectiveness seems high, PM mass emission rates are much lower than NOx and NMHC emission rates. As a comparative example, the most recent PM control regulations, the urban transit bus standards, resulted in a cost-effectiveness of $17.90 per pound of PM reduced.

XI. SUMMARY AND STAFF RECOMMENDATION

The proposed emission standards and supplemental test procedures are essential to ensure further emission reductions necessary to meet clean air goals. Although the emission reductions of this proposed regulation are not included in the current federal ozone SIP, further emission reductions to ensure compliance with the federal standard and to meet the more stringent state air quality standard for ozone and the state ambient PM standard are needed. Additionally, the amendments also ensure emission standards are harmonized with those adopted by the U.S. EPA in their 2007 Final Rule.

The technologies that would allow manufacturers to comply with the proposed emission standards and supplemental test procedures are available and being developed for commercial application. One technical requirement to ensure the effectiveness of the anticipated technologies is the availability of low sulfur, in-use diesel fuel. To ensure that the proper fuel is used for emission testing and service accumulation, the low sulfur content certification test fuel is proposed. Manufacturers will continue to have the option to use an alternative certification test fuel provided there is sufficient evidence indicating that this test fuel will be the predominant in-use fuel. Standards and requirements for low sulfur, in-use diesel fuel have been adopted federally and will be included in a separate California proposal that is currently proceeding with public review.

Estimates of statewide emission reductions resulting from the proposal are 40.3 tons per day of NOx, 1.3 tons per day of ROG, and 2.3 tons per day of PM in 2010, for California registered vehicles (i.e., not including out-of-state vehicles). Estimates of statewide emission increases resulting from the proposed harmonization of the medium-duty CO emission standard is 0.1 tons per day in 2010, for California registered vehicles (i.e., not including out-of-state vehicles). Since the proposed emission standards and supplemental test procedures are identical to those adopted by the U.S. EPA in the same time period, clean HDDEs will be produced on a national basis. Consequently, the reduction of emissions (including emissions reduced from out-of-state vehicles) would be 48.0 tons per day of NOx, 1.5 tons per day of ROG, and 2.7 tons per day of PM in 2010. As more cleaner trucks enter the fleet, emission reductions will increase – for example, 209.5 tons per day reduction in NOx in 2020.

Since the proposed emission standards and supplemental test procedures are identical to those adopted by the U.S. EPA in their 2007 Final Rule, costs to California agencies and businesses will be similar to those nationwide. With adoption of the staff's proposal, cost-effectiveness ranges from approximately \$0.29 to \$0.63 per pound of NOx plus NMHC reduced and from approximately \$3.03 to \$6.65 per pound of PM reduced. Both compare favorably to the cost effectiveness of other recently adopted emission control measures. The staff recommends that the Board adopt these proposed amendments to the emission standards and supplemental test procedures for HDDEs.

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APPENDIX A – PROPOSED AMENDMENTS TO TITLE 13, CALIFORNIA CODE OF REGULATIONS, DIVISION 3 AIR RESOURCES BOARD, CHAPTER 1 MOTOR VEHICLE POLLUTION CONTROL DEVICES, ARTICLE 2 APPROVAL OF MOTOR VEHICLE POLLUTION CONTROL DEVICES (NEW VEHICLES); SECTION 1956.8, EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1985 AND SUBSEQUENT MODEL YEAR HEAVY-DUTY ENGINES AND VEHICLES.

APPENDIX B — PROPOSED AMENDMENTS TO CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 1985 AND SUBSEQUENT MODEL HEAVY-DUTY DIESEL ENGINES AND VEHICLES.